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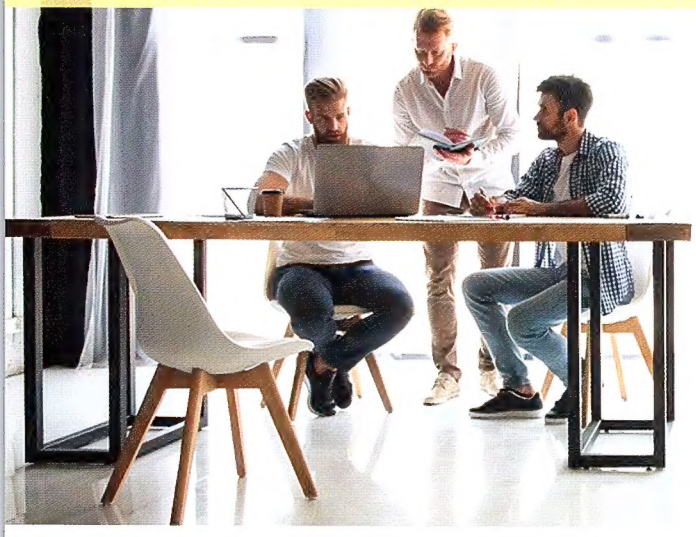

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EDITORIAL

THIS ONE GOES TO 11

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BEN MANSILL
Ben's been editing tech mags since 1994, but never with a beard until 2021.

EDITORIAL

Intel vs AMD vs Nvidia

Yes please!

It's finally happened – the big unveil of Intel's resurrection lineup of new products and technology we've been waiting for. And it's absolutely thrilling! While much of the work will have been in the pipeline pre-Gelsinger, it's the big reveal Intel absolutely had to deliver on.

On both the CPU and GPU front Intel's surprised and pleased us. The Arc GPU announcement outlined few basic tech details, but this was all about a statement of intent. A declaration of commitment that Intel is entering one of tech's hottest warzones. Until now we weren't sure if Intel really was all-in on discrete consumer graphics cards; now we know it is, and big time.

We've come from the last few months of vague hyperbole, a few photos of ex-AMD now-Intel architect Raja Koduri holding a die, and the story so far has been integrated Xe graphics – while the big hero product, the discrete consumer graphics card – only had the Xe-HPG moniker. Now there's a brand, and self-important model names that are a little cringy (Alchemist, Battlemage, Celestil and Druid), but that's the tradition in tech and they'll grow on us.

Intel also couldn't come to the party now without a DLSS/FSR technology, and one of the juicer details revealed was that indeed yes, Arc will have a form of AI super sampling.

I do like the branding. Technically Intel already has an 'Ark', being its database/wiki of chips. This is the sexy Arc. I like the name, I really do. And it's all Intel blue, of course, and with Radeon red and GeForce green, the RGB wars are officially underway! I apologise for that terrible joke and promise not to do everything we possibly can to bring it into mainstream usage.

We're hard at it digesting the mountain of announcements about the new technology inside the next gen of Intel CPUs. There's just so much and it all represents a huge departure from the incremental annual Skylake updates we've become used to. We'll be analysing it in depth in upcoming issues of *APC*. Particularly interesting is the adoption of the big/little cores architecture that's worked so well for the likes of Samsung and Qualcomm in the smartphone market. AMD remains committed (right now at least) to many big cores. It makes sense for laptops where power is critical, but is is this the right path for desktops? Time will tell!

This was all announced a few hours before this edition of *APC* went to press, so by the time we send the next issue to the printers we'll have it all figured out and will have much to share.

What a fantastic industry we cover. A new era just began!

BEN MANSILL

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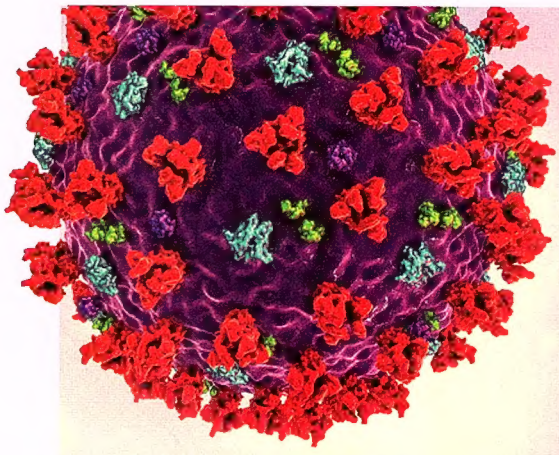

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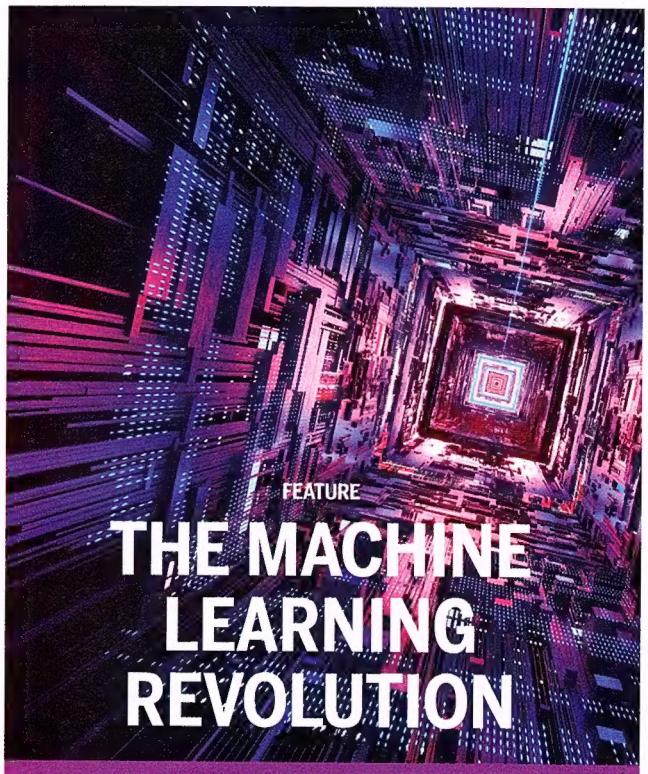

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WINDOWS 11

"Championing technology doesn't mean we're unrelenting yes-men and -women, however, and APC aims to be as objective as possible in all our coverage."

HOW WE DO IT

Inside *APC*

Find out all about *APC*'s editorial policies, test practices, how to read the benchmark results, and more.

APC is Australia's oldest consumer technology magazine – having been consistently in print for forty years, since our first issue way back in May 1980 – and we take that heritage and responsibility very seriously. While our focus is obviously on the personal computer the very definition of the PC has changed and shifted markedly since the early 1980s. As such, we touch on many other areas of tech, too, from smartphones and apps to peripherals, accessories, and beyond. We have two goals: to find the best modern tech and to help you make the most of it.

We're also an open church in terms of platforms. We know most people aren't wed to a single brand's products and use a variety of devices. And, like you, *APC*'s journalists want to know what's good in tech – no matter what platform it resides on.

Independent reviews

Championing technology doesn't mean we're unrelenting yes-men and -women, however, and *APC* aims to be as objective as possible in all our coverage. That means identifying the best products from multiple perspectives – the best performance, best value and best features and, ideally, the products that offer the best mix of these three attributes.

As a matter of policy, reviews published in *APC* are not shared with product-makers prior to print. We will contact vendors under certain conditions; for example, if we have a problem testing a product that seems to indicate it may be faulty, or to invite a vendor to clarify how a particular feature works. If an *APC* reviewer has any potential conflicts of interest involving a brand, the review will always be assigned to another writer.

Labs testing

APC strives to conduct the most rigorous, objective scientific tests and benchmarks we can so as to make our reviews as unbiased as possible. We use a variety of tools and programs for this, including many freely available benchmark suites for assessing media encoding, general system performance including storage read and write speeds, gaming and battery life.

In most cases, for the benchmark results published in *APC*, you can assume that higher is better. There are certain tests that deviate from this rule where the opposite is true; in those cases, we've flagged the results with a note explaining as such.

We use both tables and graphs for displaying results; the latter offers better ease-of-readability, but tables are more compact, so we use these in most cases where thoroughness is preferred. ■

APC TESTBED

The current *APC* testbed used in the Labs for benchmarking all components. This testbed is updated as new and relevant technology comes on stream.

CPU	AMD Ryzen 7 5800X
Motherboard	Asus ROG Crosshair VIII Dark Hero
GPU	MSI GeForce RTX 3080 Gaming X Trio
Memory	2x8GB Team T-Force Xtreem ARGB DDR4-3600
Primary SSD	Adata S70 2TB NVMe
Secondary SSD	Samsung 980 Pro 500GB NVMe
Cooling	Nzxt X73 360mm AIO
Case	Thermaltake Core P8
Power Supply	Corsair AX1000

APC AWARDS

***APC* Hot Product**

When a reviewed product scores 4.5 out of 5 or higher, it carries the Hot Award. These are products that exceed expectations and deliver a quality experience up there with the very best.

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TECHNOTES

ALL THE NEED-TO-KNOW TECH NEWS

Intel Architecture Day 2021: Alder Lake CPUs

12th-gen reveals total design overhaul.

Intel's Architecture Day 2021 was full of deep-dive disclosures, with this year's topics focusing on the architectural details of the company's forthcoming Alder Lake CPUs that will span from the desktop PC down to ultra-mobile applications by combining two types of cores in a hybrid design, a first for an x86 desktop PC chip.

However, unlike other Arm hybrid designs we've seen that are tuned for power efficiency, Intel has tuned its Alder Lake chips for the highest performance possible. Intel claims that Alder Lake's high-performance cores come with an average 19 percent IPC improvement over the Rocket Lake chips, marking the fastest high-performance core the company has built, and that its new efficiency core offers up to five times the power efficiency of Skylake.

Intel's Alder Lake also supports features like PCIe 5.0 and DDR5 that leapfrog AMD and Apple in connectivity technology and also outstrip Ryzen's core counts in mobile designs, potentially a much-needed win when Alder Lake comes to market in Autumn 2021.

Intel shared plenty of new information about its latest CPU architectures, but we're focusing on Alder Lake in this summary, with a much closer inspection in the next *APC*.

• The Alder Lake SoC will span from desktop PCs to ultramobile devices with TDP ratings from 9W to 125W, all built on the Intel 7 process. The desktop PC comes with up to eight Performance (P) cores and eight Efficient (E) cores for a total of 16 cores and 24 threads and up to 30 MB of L3 cache for a single chip.

• Intel's new hyper-threaded Performance (P) core, which comes with the Golden Cove microarchitecture designed for low-latency single-threaded performance, comes with an average of 19 percent more IPC than the Cypress Cove architecture in Rocket Lake. It also supports AVX-512 and AMX (a new AI-focused matrix-multiply ISA) for data centre variants (both are disabled on consumer chips).

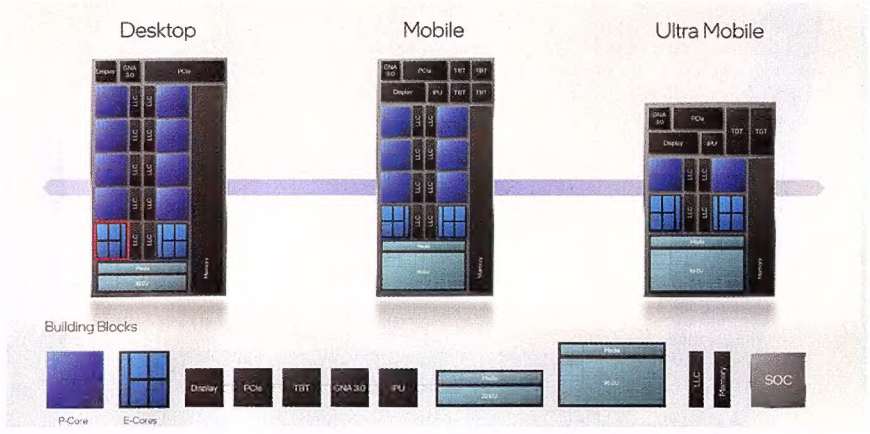
• Intel's new single-threaded Efficiency (E) core, which comes with the Gracemont microarchitecture, is designed to improve multi-threaded performance and provide exceptional area efficiency (small footprint) and performance-per-watt. Four of these small cores fit in the same area as a Skylake core and deliver 80 percent more performance in threaded work (at the same power). A single E core also delivers 40 percent more performance than a single-threaded Skylake core (at the same power) in single-threaded work (caveats apply to both).

• Intel's Thread Director is a hardware-based technology that provides enhanced telemetry data to the Windows 11 scheduler to assure that threads are assigned to either the P or E cores in an optimised manner, potentially easing one of the major pain points for a hybrid architecture in a standard desktop environment. This is the sleeper tech that enables the hybrid architecture.

• Alder Lake does not support AVX-512 under any condition (fused off in P cores, not supported in E cores) to ensure an even ISA application.

• Alder Lake supports either DDR4 or DDR5 (LP4x/LP5, too). Desktop PC supports x16 PCIe Gen 5 and x4 PCIe Gen 4, while mobile supports x12 PCIe Gen 4 and x16 PCIe Gen 3, Thunderbolt 4, and Wi-Fi 6E.

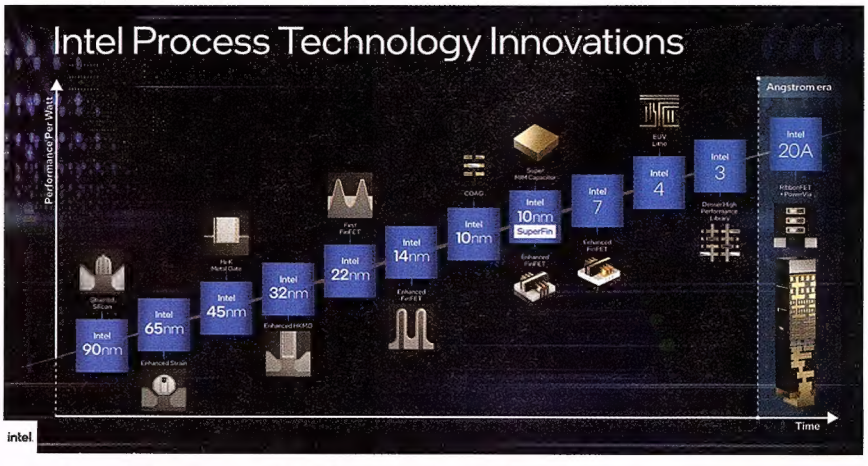
PAUL ALCORN



Alder Lake
Core/Cache

Up To	Up To	Up to
16 Cores	24 Threads	30MB
8 Performance 8 Efficient	2T per P-core 1T per E-core	Non-inclusive LL Cache

Above: The big/little architecture even allows for an ultra-mobile dual-core CPU to feature another eight Efficiency cores.
Right: Efficiency cores won't support hyperthreading, but can increase their frequency to tackle bigger workloads.



An unusually detailed roadmap covers Intel's ambitious plans through to 2025.

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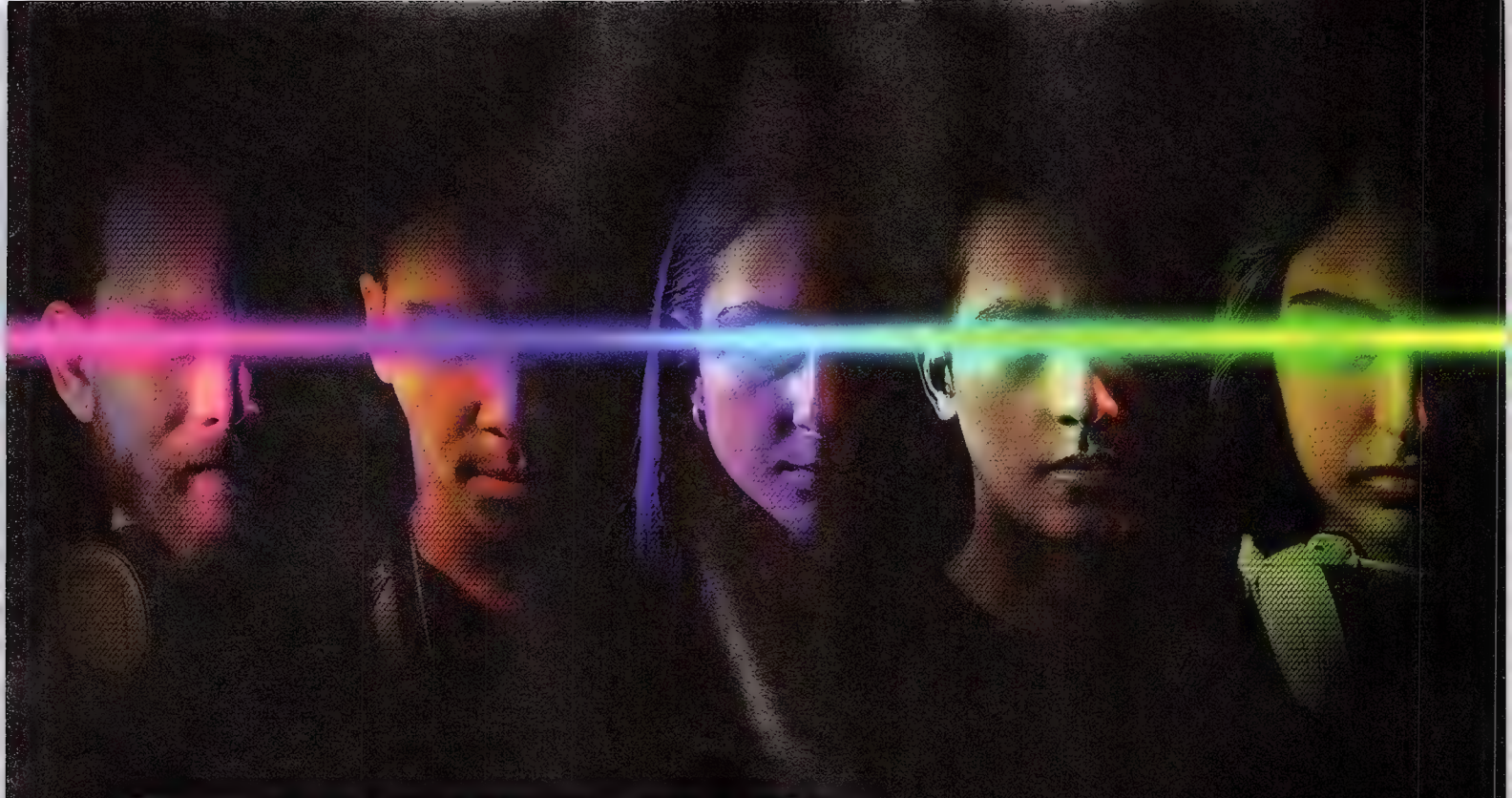

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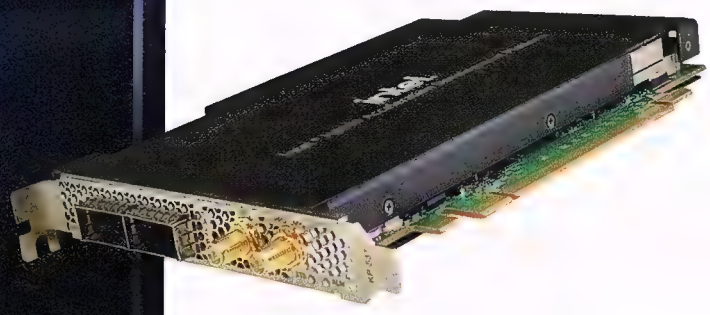
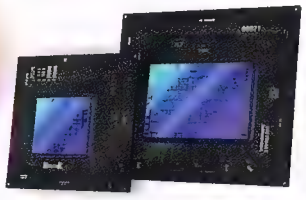


Above: An early engineering Arc card was shown.
Left: Ex-AMD and now Intel chief architect Raja Koduri.
Below: Arc GPU dies.



Intel Architecture Day 2021: Arc GPUs

A sneak peek at the Xe-HPG GPU architecture.

Intel Alchemist, aka DG2, GPUs are set to become the first gaming graphics cards spun out of the Intel Xe-HPG yarn, something that is promised to be the basis for many more competitive GPUs from the chipmaking Goliath. Alchemist also happens to be the first offering from Intel's high-performance graphics brand, Arc, which covers hardware, software and services. It's all set to kick-off at the start of next year, when we'll see Intel put its best foot forward in hopes to heave open the hydraulic grip of Nvidia and AMD over gaming GPUs.

Xe-HPG is born out of both Intel's Xe-LP and Xe-HPC architectures, but with some specialised twists. As Intel has since explained at its Architecture Day 2021, Xe-HPG is built for gaming first.

The new Xe-core within Alchemist GPUs features 16 Vector Engines and 16 Matrix Engines, which is actually double that found in Xe-HPC. Intel says this was a decision it made to put gaming first for its Alchemist GPUs, and was necessary to build out big gaming graphics cards.

Those Matrix Engines are extremely interesting, too. These cores deliver acceleration for AI workloads, such as inference tasks for deep learning. Think of them like Intel's version of Nvidia's Tensor Core. Intel plans to use these cores for all manner of AI tasks, but namely it's the acceleration of its Xe Super Sampling (XeSS) upscaler that has us excited from a gaming point-of-view.

Zooming out some, and things get really interesting for this gaming architecture. Four Xe-cores combined become a Render Slice, and within each Render Slice resides up to four Ray Tracing Units.

These units accelerate real-time ray tracing workloads, which Intel has confirmed will be supported with its Alchemist graphics cards.

That's not the only DX12 Ultimate feature on the agenda, either. Intel has affixed fixed function units within a Render Slice to support sampler feedback and mesh shading on Alchemist.

Up to eight Render Slices combined will make up the top rumoured Alchemist graphics card, which already seems like a mighty amount of silicon to take on AMD and Nvidia at their own game.

Onwards to memory configuration and it appears as though Intel is keen to match AMD and top Nvidia in raw memory capacity. Paired with Intel's Xe-HPG GPU is said to be up to 16GB of GDDR6, operating between 14Gbps and 18Gbps. That's all information pulled right from Intel's site in the aforementioned leak.

Intel is suspected to utilise a 256-bit bus for the top 512 EU graphics card, which will put it on par with Nvidia's RTX 3070 and AMD's Radeon RX 6800.

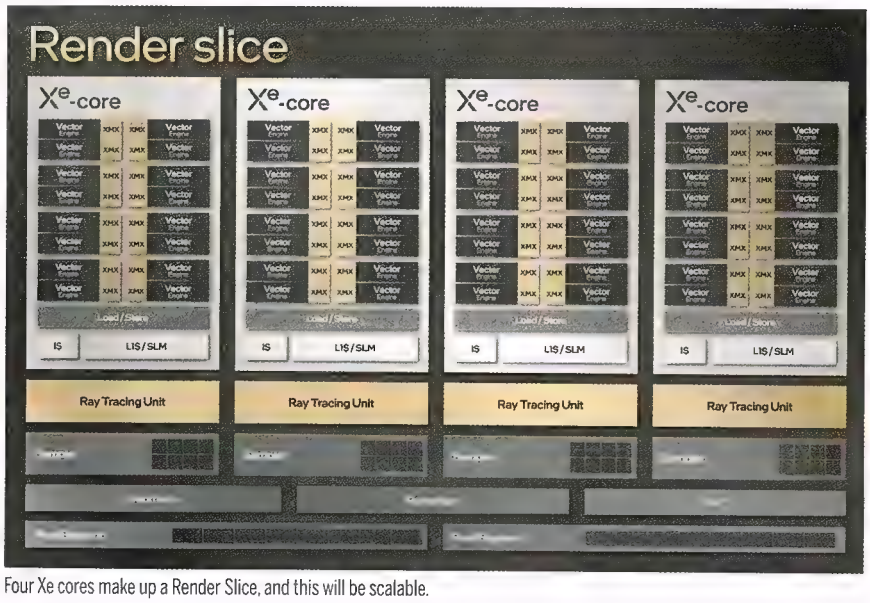
Intel Alchemist performance

All rumours allude to Intel Alchemist's top chip taking aim at Nvidia's GeForce RTX 3070. Intel has released information regarding the performance/Watt and frequency boost we can expect with Xe-HPG over Xe-LP, at least, and it's looking like a 1.5x gain in both regards.

That could put Alchemist GPU clock speeds upwards of 2GHz, as Xe-LP in discrete form, the Iris Xe Max, is capable of up to 1.65GHz. At least there is a possibility for a truly competitive card here, then. And even if it's not an RTX 3080 Ti, with relatively low numbers of any graphics card out in the market today, a new manufacturer with its own dedicated GPU supply could prove itself of critical importance for gamers trying to snag any discrete GPU in 2021.

Yet with TSMC at the helm, a company that is under a lot of pressure to deliver chips as is, can Intel really tip the scales? Fingers crossed.

RYAN SMITH ■



Four Xe cores make up a Render Slice, and this will be scalable.

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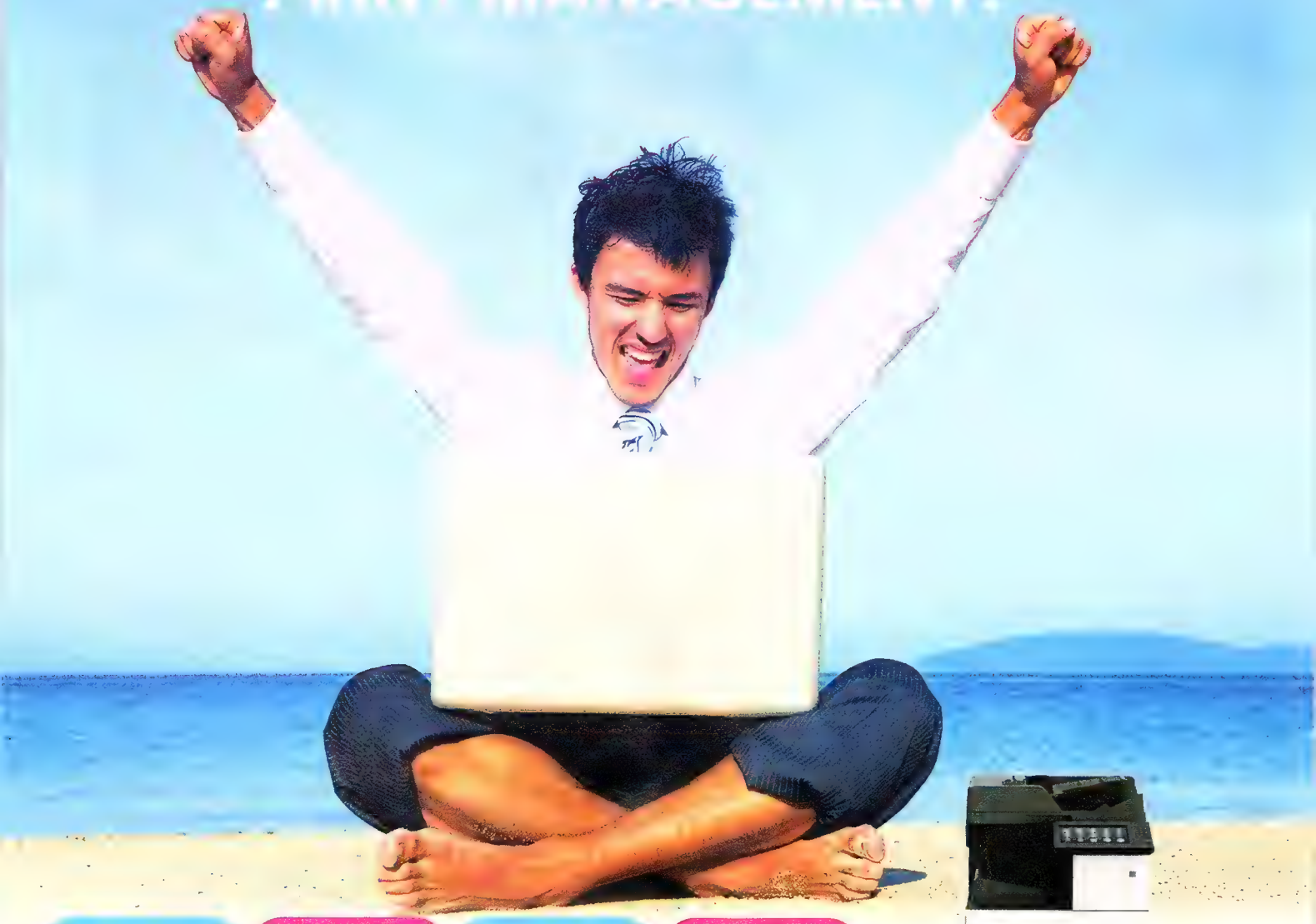

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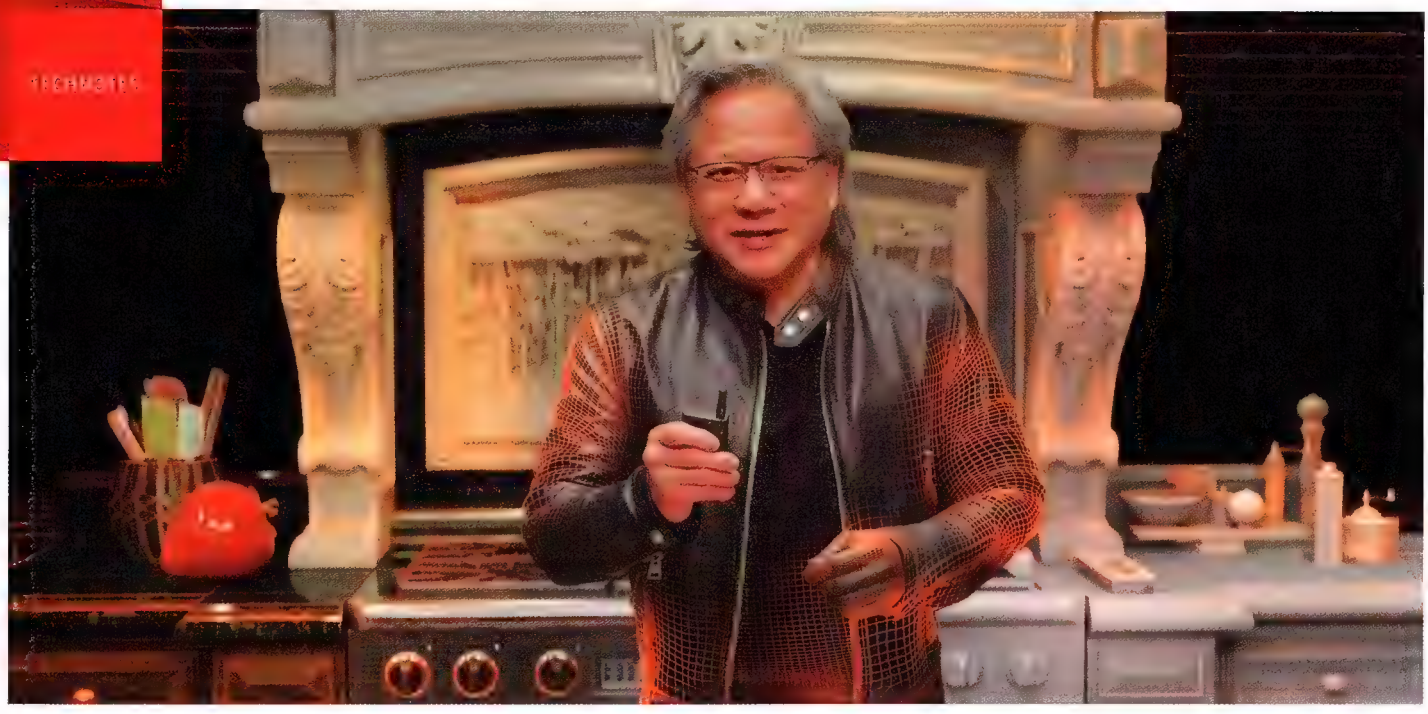


TECH BRIEF

Jensen's Kitchen was a lie

Nvidia reveals GTC 2021 keynote nearly 100 percent fake.

Nothing is real and anything is possible – Nvidia CEO Jensen Huang's iconic kitchen, where he presented three pandemic-era keynote addresses in 2020 and 2021 – was almost entirely fake, including Huang himself (though his voice was real), during the company's GTC 2021 keynote earlier this year and nobody even noticed.

The virtual presentation was cooked up using something called Nvidia Omniverse, a multi-disciplinary collaboration tool for creating 3D virtual workspaces. For an annual keynote address known for impressive technical displays, this one certainly delivered.

Most viewers had no idea they hadn't seen the real Huang speaking from his real kitchen until a new documentary by Nvidia was released that detailed the efforts that went into making that presentation.

Nvidia pulled off arguably the best shock reveal of the year – using astonishing virtual technology.

A video of Nvidia's DGX Station A100 workstation was also entirely generated using Omniverse.

The news comes as a shock to just about everyone in the industry, given that the virtual presentation in April 2021 raised no suspicions among the tens of thousands of industry professionals and press who covered the event. Nvidia's Omniverse was that good at recreating what has become a very familiar scene.

In a blog post on Wednesday, Nvidia talked about the experience of recreating a space for which tech enthusiasts have developed a real attachment. "Jensen's kitchen" was a pandemic staple for PC hardware fans who were used to watching or even attending much larger, more heavily produced launches.

"The demo is the epitome of what GTC represents: it combined the work of Nvidia's deep learning and graphics research teams with several engineering teams and the company's incredible in-house creative team," the company said.

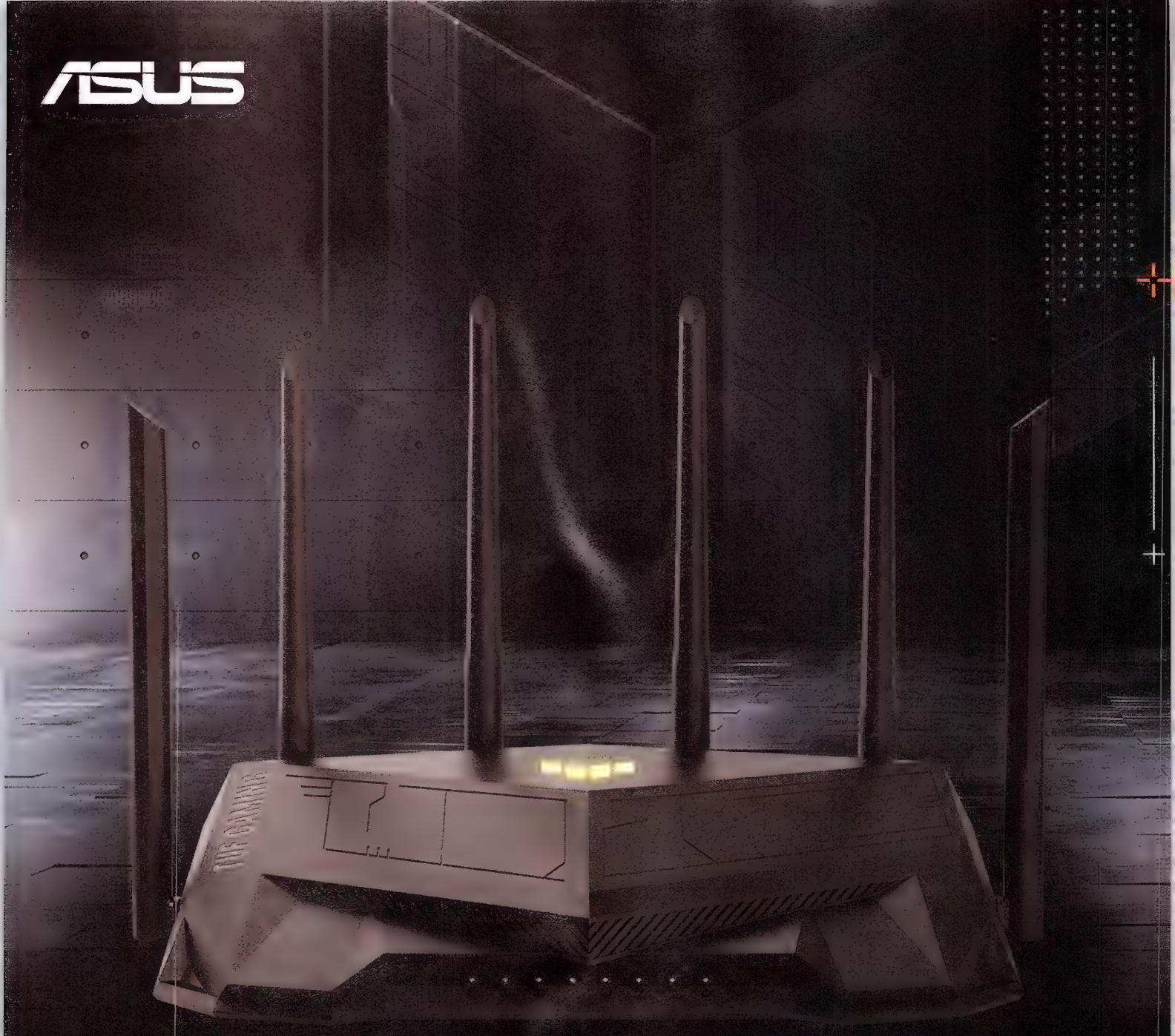
"To create a virtual Jensen, teams did a full face and body scan to create a 3D model, then trained an AI to mimic his gestures and expressions and applied some AI magic to make his clone realistic.

"Digital Jensen was then brought into a replica of his kitchen that was deconstructed to reveal the holodeck within Omniverse, surprising the audience and making them question how much of the keynote was real, or rendered."

Jensen's kitchen, meanwhile, brings its own understated charm to Nvidia's recent keynotes. There's nothing quite like seeing Huang pull the brand new RTX 3090 out of his oven during the Nvidia Ampere reveal last year, and for many people dealing with lockdowns and social distancing due to the pandemic, the keynotes were a way to digitally connect with fellow enthusiasts in the comments section of the livestream.

It was a natural choice then to make Jensen's Kitchen the demonstration of Nvidia's Omniverse tool, which is all about creating realistic 3D workspaces where people can meet and collaborate. Cool as it is, though, we still prefer the real thing. ■

ASUS



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END USER

Fortnite isn't a game, it's a lecherous advertising platform

For lack of connections to other media properties, *Fortnite* would lack a personality of its own, writes Shaun Prescott.

Last month *Fortnite* announced a new Imposters event, a ten player mode pitting eight agents against two undercover 'imposters'. It's a social deduction game basically, and a dramatic departure from the main game's battle royale bread and butter. It's also pretty heavily inspired by *Among Us*, an indie game phenomenon developed by three people that blew up in 2020, after two years spent in complete obscurity.

This is hardly a new phenomenon in games: clones are as old as the medium, and *Fortnite* itself gained popularity by quickly pivoting from a failing co-op game to a *PUBG*-aping battle royale. Some *Among Us* developers expressed disappointment following the mode's announcement, and studio Innersloth's third-party business development head revealed on Twitter that he had previously "reached out" on the subject of collaborations. But their disappointment doesn't make it legally wrong.

But it does kinda suck for Innersloth because, after all, *Fortnite* is no stranger to collaboration. In fact, it has somewhat transcended the status of 'game'. Nowadays it's basically a platform for various lucrative marketing tie-ins, whether promotions for the Marvel Cinematic Universe, or high-profile pop stars like Ariana Grande and Travis Scott. Other games advertise inside *Fortnite*: *God of War*, *Halo*, and *Rocket League* have all appeared in the game (the latter is owned by Epic Games).

SHAUN PRESCOTT
Author, *PC Gamer* editor and passionate technology observer, Shaun covers trending tech topics for *APC*.

Shorn of these connections with well-established franchises and personalities, *Fortnite* is a curiously hollow game. It doesn't have an identity of its own: it's a strange amalgamation of zeitgeists, with a straight-out-of-the-box phone game art style reminiscent of Zynga's slappers (credit where it's due, though: *Fortnite*'s improvisational building aspect is definitely unique in the battle royale field).

Epic Games does give 'personality' a red hot go, and obviously there are a lot of players – probably millions of them – invested in how the game's optional plot develops between seasons. But overall, it's less of a game and more of a metaverse, though it's not quite even there yet. Look to something like *Second Life*, or *Roblox*; those are legit metaverses, with their persistent worlds, meaningful in-game economies (people get rich designing *Second Life* apparel) and town square structures: these are less games than they are portals into various virtual ways of interacting.

But *Second Life* and *Roblox*, despite being obscenely popular with their converts, don't make a huge dent on the gaming industry – or culture – as a whole. They're weirdly self-contained. *Fortnite* on the other hand does, and it's quickly starting to resemble a kind of ruinous roaming hurricane, subsuming everything in its path. Its moment-to-moment free-to-play gameplay is just grist to the mill of its lucrative collaborations with other gargantuan entertainment properties.

By now everyone's heard of *Fortnite* addiction, and the difficulty parents have weaning their kids off games – harder nowadays given their cross-platform ubiquity. In 2019 one Canadian lawyer filed a legal notice against Epic Games, accusing it of using psychological techniques in order to hook players to *Fortnite*.

Those things are terrible, but *Fortnite* also represents a more abstracted malaise, a kind of hollowing of the popular imagination, where entertainment is just a crush of familiar multi-million dollar franchises, where its proximity to "art" has been utterly eroded. Over a decade ago when the "games in art" conversation was indelicately raging, could we have imagined logging into *Fortnite* in order to grind enough V-bucks to afford the Captain America skin in order to look amazing during the *Fortnite* Marshmello gig?

Anyway, the art question doesn't matter so much as whether we want to keep engaging with a phenomenon that so transparently seeks to enslave us, sucking up every marketable object in its trail, whether EDM or the efforts of a tiny game studio who managed to hit a winner. ■

Epic Games has been increasingly leveraging *Fortnite*'s popularity for vaguely-related marketing pushes.

RANDOM ACCESS

Where did all the laptops go?

If your top pick for a new laptop is sold out you might be able to bag an even better deal if you're willing to do a bit of digging, reports *APC* laptop nerd Joel Burgess.

While there's been no shortage of laptops flowing through the pages of *APC*, we have noticed that a lot of them are actually reasonably difficult to find out there in the real world. Yes, part of this is the complicated model options that manufacturers like to range in order to bamboozle customers into buying devices with higher margins – that will always happen, but there's also been a big impact from a lack of processors.

According to a report by *Bloomberg* in August, chip fulfillment on business orders is still sitting at around 20 weeks, the longest waiting period since it was first measured in 2017.

While many larger PC manufacturers seem to be able to accommodate the lag, newer PC manufacturers like Microsoft seem to be struggling to meet demand for some of its Surface devices. Even across laptop brands with bigger market shares, devices that have gotten a lot of attention or that offer particularly good value are frequently 'sold out' and have been for months in some cases.

In June, Acer's Chief Operating Officer Tiffany Hang said that on any given day the company was only able to fill "50 percent of the worldwide demand", with the company forced to shift away from supplying lucrative gaming laptops in order to ensure the affordable education-focused devices are available for kids.

JOEL BURGESS
When not reviewing PCs for *APC* and writing our funny pages, Joel likes to ponder tech and how it's used.

It doesn't look like that equation is going to change anytime soon either, with Gartner estimating that semiconductor shortages will impact laptop production at least until the second quarter of 2022.

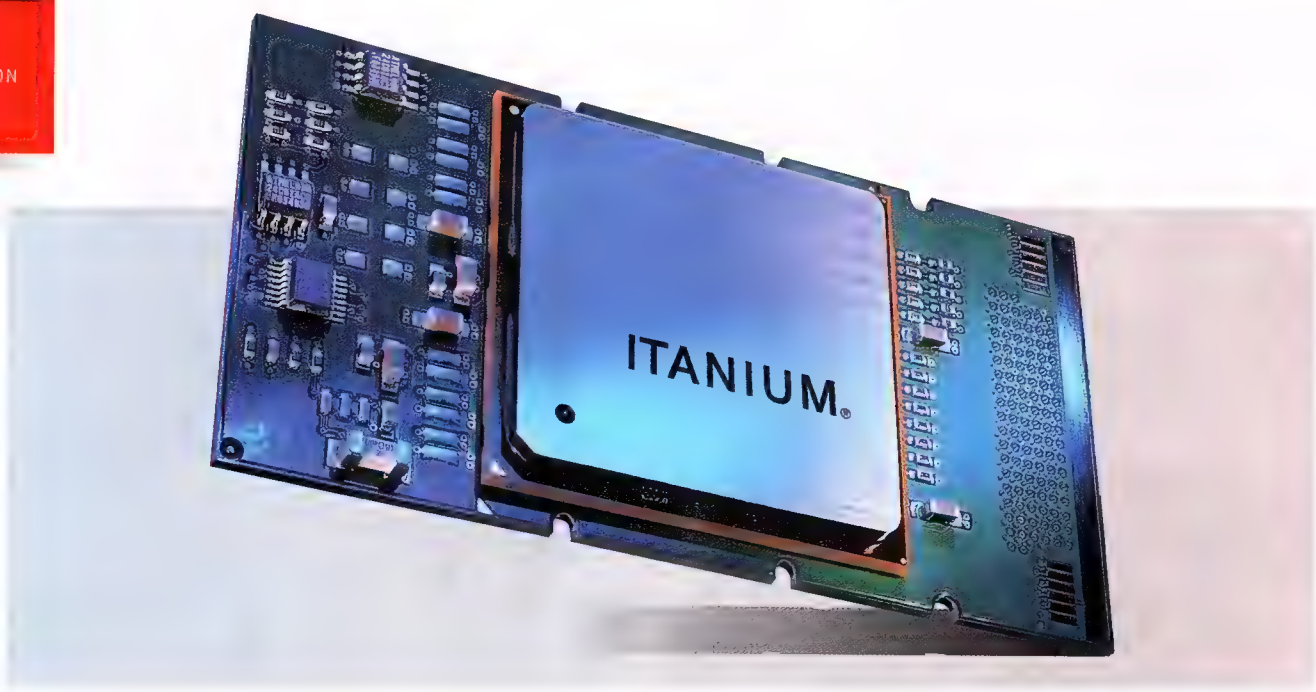
There's speculation that the impending release of Windows 11, with its restrictive CPU compatibility constraints, might make the crunch for specific devices even more challenging when it launches late in 2021. You can check to see if your Windows 10 device is compatible with Windows 11 at **microsoft.com/en-au/windows/windows-11**, but unless you've bought your laptop recently there's a good chance it won't be compatible, seeing as even some of Microsoft's own Surface devices don't even make the cut.

Fortunately, demand for PCs globally is at least looking like it's starting to slow from the major boom earlier in the year. 2021's second quarter global growth in the PC market was only 13 percent according to market research company IDC, down from projections of 18 percent and much lower than the first quarter's 55 percent growth.

The situation isn't quite as dire as the GPU shortage was earlier in the year since you can still get a decent laptop if you're willing to be a little flexible on the exact model you want.

So while your first choice of laptop might be 'sold out', there's at least plenty of alternatives out there to be investigated. It might even be the perfect time to consider one with an AMD Ryzen CPU that occasionally appears in the indexes of online stores. If you're flexible there's even a handful of great deals around on laptops that were previously too overpriced to really consider. While you might not get what you initially intended if you're savvy you might even walk away with a better deal. ■

"There's speculation that the impending release of Windows 11, with its restrictive CPU compatibility constraints, might make the crunch for specific devices even more challenging when it launches late in 2021."



TWO BITS

Intel ends Itanium shipments

The great experiment is no more.

In late July, Intel ended shipments of its Itanium CPU family. It marked the end of what some in the industry claimed to be the architecture that would supplant x86 as the dominant CPU architecture. Itanium was a 64-bit processor with a brand new IA-64 Instruction Set, and was developed by Intel in partnership with Hewlett-Packard. It was designed to better suit modern workloads and introduce a new programming method that was free of the legacy complexity of x86 that dated back to the 8086 processor of the late 1970s.

During the early 1990s, as the internet and datacentre demand exploded, there was a need for exponentially greater CPU processing and parallelism. SPARC- and IBM Power-based systems and not x86 formed the backbone of the enterprise market and Intel feared it would fall behind in the race to shape (and take profits) from the massive growth that was projected through to 2000 and beyond.

What began as a promising architecture quickly ran into difficulties. To get the best out of an Itanium system, software needed to be completely rewritten. This placed a heavy burden on developers, many of whom were forced to relearn their skillsets from scratch. This mightn't have been such a problem in the longer term, but with the release of AMD's x64 architecture, developers could use their existing skillsets as x64 was backwards compatible with years of established operating systems, code, and software. Itanium represented a revolutionary leap with a pie in the sky future whereas AMD's evolutionary upgrade from x86 was almost as promising, yet much easier to develop for, without the need to radically alter existing hardware, software systems, and infrastructure. To this day, enterprise teams don't like to scrap everything unless there's a compelling reason to do so. Itanium was never able to provide a compelling enough use-case to entice corporations to take on the expense.

The writing was on the wall. Intel quickly adopted the x64 instruction set and Itanium was relegated to enterprise systems that were already optimised for it. In fact Intel and HP pushed Itanium for longer than they should have. Was there an element of hubris involved? Or was it an attempt to recoup all the billions of dollars spent on Itanium's development? Both Intel and HP will tell you that customers still wanted it, and honestly, they would be at least partly right.

Fast forward 20 years and x86 remains the dominant performance CPU architecture. ARM was developed with minimal power consumption and heat generation for the entirely new class of mobile devices, something that x86 is not suited for. Despite its legacy baggage, new instructions are still being added. Perhaps Itanium's legacy is more 'if it aint broke, don't fix it'. Itanium addressed a problem that didn't really exist. Was it Intel's plan to dominate the market, as a corporation is want to do? Or was it ahead of its time? Perhaps it was just executed poorly. Whatever the reason or reasons, The Itanic is no more. The rise and rise of multi-core architectures, interconnect technologies, and countless billions of investment dollars means it's unlikely we'll see a fundamental redesign or replacement of the x86/x64 CPU anytime soon. Rest in peace, Itanium. ■

CHRIS SZEWCZYK
A life-long PC tech enthusiast, Chris has worked acoss the industry in many areas as a product and technology expert.

Intel gave Itanium its best shot and a long life, but the ubiquity of x86 won in the end.

TECH TALK

China's crypto crackdown

The beginning of the end for the latest surge in cryptocurrency prices seems to have finally arrived.

By the time you read this, maybe something else will have happened and prices will be heading back up. But realistically, China's crackdown on mining and cryptocurrency use in general looks to have radically altered the crypto landscape.

This isn't the first time China has taken a negative stance toward bitcoin and its ilk, but in the most recent surge, things apparently got a bit out of hand. Now, the Chinese government is taking a dual-pronged approach to attacking crypto. First, China has tightened its restrictions on banking and payment companies dealing with cryptocurrencies. While the government already limited what banks could do with crypto since 2013, the latest directions from the People's Bank of China, as an example, state that institutions must not accept virtual currencies in any form or provide the ability to exchange virtual currencies for the Chinese yuan or other foreign currencies. There are also restrictions on storing crypto for people looking to invest, and 2017's ban on ICOs (initial coin offerings) remains in effect.

The new restrictions took effect back in May and had an adverse effect on bitcoin prices, at least for a while. But cryptocurrencies can be resilient and unpredictable beasts, and some thought they might recover. Then China dropped the mining banhammer. It started with Inner Mongolia banning mining in March, then spread to Qinghai, Xinjiang, Yunnan, and Sichuan. These were attractive locations for mining operations, thanks to their cheap electricity costs, not to mention apparently ready access to supplies of mining hardware – it's no surprise that many of the farms appear to use large numbers of graphics cards of the same model.

The ban wasn't just against any future mining projects. Mining groups were apparently instructed to shut down within days – authorities in Sichuan reportedly told miners on June 18 that they had until June 20 to halt. And in a case of Big Brother watching you, Inner Mongolia established a hotline for citizens to report on suspected mining operations. The message is clear: China wants crypto miners to leave.

JARRED WALTON
Jarred Walton has been a PC and gaming enthusiast for over 30 years.

It's estimated that around 65 percent of all power used by the bitcoin network was in China in 2020. Perhaps more telling, with the government's crackdown on crypto mining, the global network hashrate of bitcoin plummeted from a high of 180.6EH/s (exahash per second) on May 13 to a low of around 85EH/s on July 2. Ethereum wasn't hit quite as hard, dropping from a high of 644TH/s on May 20 to a low of 478TH/s by late June.

It's not just hashrates declining, though. Large quantities of used GPUs are being sold in China, in lots of 100 or more. Which, as far as I'm concerned, is great news. The demand from crypto miners may be drying up, and supply appears to be improving, but the lingering effects of the pandemic and worldwide shortages on various chips are still a problem. ■

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COOLER MASTER ORB X

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If you're looking to upgrade your office with a new immersive gaming/productivity rig and you've got a cool $10K to drop on it, then it's worth considering this oversized Fabergé egg from Cooler Master. The Orb X Game Pod is an immersive gaming chair that wraps around you like a scorpion and carries your choice of up to three 27-inch gaming screens or a 49-inch ultrawide (not included). The Orb X comes with an integrated 2.1 audio system that should sound pretty sweet, but probably should be 5.1 or 7.1 considering how much you're dropping on it.

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Google's new budget Buds bump up the bass.

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Alienware M15 R6

How does the latest ultra fast gaming laptop from Alienware stack up against its recent AMD alternative?

Dell has split its AMD and Intel Alienware M15 offerings into two camps this year: the R5 and R6. We took a look at the Ryzen based R5 last month in *APC* 497, and while it was a nice machine it wasn't priced particularly competitively, and only offered a 165Hz screen when most of the competition features 240 or 300Hz screens for the same cost. Clearly Alienware was trying to save the fastest screens for its M15 R6 offering to make it seem like a particularly premium offering.

The M15 R6 range starts with an Intel Core i5-11400H CPU, 16GB RAM and Nvidia RTX 3060 GPU configuration with a 15.6-inch 165Hz FullHD display. Dell is selling this entry level model for $2,799, which is about $800 more expensive than some of the better value comparable units around. At the other end of the range is the Alienware M15 R6 with an Intel Core i7-11800H, 16GB of RAM, and a Nvidia RTX 3080 (125W) on a 15.6-inch 360Hz display, which has an RRP of $4,499. This model was on sale for $3,824 at the time of writing, which puts it into a reasonable price point considering it has the fastest screen currently available to gamers on laptops, but you can get similar specced units with 240Hz monitors for more than $500 less than this sale price, which makes sense for anyone who doesn't have a gaming sponsor paying for their laptop.

As we said on the M15 R5, the R6 has nice build quality with a great keyboard and a good looking gaming chassis. The 15.6-inch 360Hz screen is reported to have a 1ms response time, G-Sync and the new Advanced Optimus auto GPU switching technology from Nvidia, so there isn't much in the way of advanced screen features that you'll miss out on.

The i7-11800H on the M15 R6 was generally comparable to the AMD Ryzen 9 5900HX on an R5 across our suite of CPU benchmark tests, but it did land 14 percent behind it in some media encoding tasks. When it comes to gaming, everything we threw at it for Full HD 'Ultra' was above 92fps with less demanding titles getting over 200fps on Ultra settings. We did note particularly good performance on high framerate games, which is a good feature for a device with such a high refresh rate.

The Advanced Optimus GPU switching tech did a bit to help this unit last about 18 percent longer in general work tasks than the M15 R5. Despite this improvement however, the 84Wh battery wasn't outside the realm of gaming laptops lasting three hours and 24 minutes in PCMark 10 and five hours in 1080p movie playback battery benchmarks.

While we wouldn't recommend the entry models based on value, you always pay a premium to have the best equipment around and there just aren't that many laptops with 360Hz monitors available. If you need this, then the top spec M15 R6 is a great gaming laptop that is at least reasonably priced.

	Alienware M15 R6	Alienware M15 R5
PCMark 10 - Overall (score)	6,777	5,953
Max CPU Temperature (C)	100	103
1080p movie playback (HH:MM)	05:01	04:36
HWBot x265 - 1080p (Ave fps)	54.721	58.805
3DMark Time Spy (score)	10,817	9,596
The Division 2 - 1080p Ultra (fps Av.)	92	81
CrystalDiskMark Read (MB/s)	3,221	3,463
CrystalDiskMark Write (MB/s)	3,019	3,128

Specifications

Windows 10Home 64-bit; 15.6-inch 360Hz G-Sync display @ 1920 x 1080 pixel resolution; Intel Core i7-11800H CPU; 16GB RAM; Nvidia GeForce RTX 3080 (125W) GPU; 1TB PCIe SSD; 84Wh battery (5hours 1080p movie playback); 35.6 x 27.2 x 2.3cm; 2.7kg.

The 360Hz 15.6-inch M15 R6 is a solid gaming laptop with a nice keyboard and premium price tag. **Joel Burgess**

★★★½☆

$2,699 | asus.com/au

Asus ZenBook Duo UX482

Will a second laptop screen really allow you to find your inner zen?

We haven't always been fans of Asus's various avant garde placements of additional screens on its laptops, but one space it definitely works well is on the Duo. The Duo UX482 incorporates a 12.65-inch IPS-level screen above the keyboard, making use of what is generally a lot of dead space with a useful second screen. The ScreenPad Plus attaches to the hinge mechanism to tilt seven degrees up off the keyboard, to line up more seamlessly with the main screen. Whether you're gaming or working, this additional viewing space is amazingly convenient, allowing you to keep track of things that would usually happen offscreen.

The main 14-inch display on the Duo UX482 has a pretty standard 1,920 x 1,080 pixel resolution, but it is brighter than most, with a 400nit peak brightness, and it has been validated to 100 percent sRGB colour reproduction by Pantone, so it's fine for any standard RGB colour work.

In order to make way for the additional screen, there are some keyboard rearrangements required. Instead of being centered, the trackpad is shifted to be in line with the keyboard. The keys and trackpad are nice enough to use and if you add a mouse to the equation then it's a really efficient setup.

The device is running an Intel Core i7-1165G7 CPU, which has good boost speeds but is only a quad core, so it's some way off the performance you'll get in gaming laptops. Locally the Duo 482 is only available in one configuration that comes with a discrete Nvidia GeForce MX450 GPU. This graphics card isn't really a fully fledged gaming GPU but it does offer between 20 to 30 percent better framerates in games over the integrated Intel Iris Xe Graphics processor. It's still not quite capable enough to get playable framerates on modern games using 1080p Ultra settings, but if you dial down the graphics options you'll get between 30 and 60fps across most games at 1080p. This extra GPU bump will also potentially streamline any workflows that do a bit of graphical processing.

Despite having two screens the ZenBook Duo 482 actually has a really solid battery life thanks to a generous 70Wh battery. The Duo 482 managed 10 hours and 52 minutes in general work tasks and 11 hours and 10 minutes in 1080p movie playback. What's perhaps even better is that it is charged via the thunderbolt port, which means that the accompanying charger actually has a really compact power brick that isn't a burden to carry with you.

If cost is a serious consideration then it's hard to justify that second screen. If, however, you're a power user that needs multiple screens to run screen capture apps, host online meetings, keep track of stocks or stats while working on something else or you have to have chat windows permanently open then this is a sleek multi-screen option without any real competition.

	Asus ZenBook Duo UX482	Asus ExpertBook B9400CE
PCMark10 - Overall (score)	4,854	4,783
HWBOT x265 2.2 - 1080p (fps)	21.09	18.186
3DMark Time Spy (score)	1,857	1,500
Tom Clancy's The Division 2 - Low 1080p (fps)	38.00	23
Battery life - 1080p video playback (h:min)	11:10	11:24
Peak CPU temperature (°C)	96	100
CrystalDiskMark Read (MB/s)	3,515	3,495
CrystalDiskMark Write (MB/s)	2,994	2,311

Specifications
W10 Home 64-bit; 14-inch 400nit IPS display with 1,920 x 1,080 pixel resolution; 12.65-inch IPS ScreenPad Plus display at 1920 by 515 pixels; Intel Core i7-1165G7 CPU; Intel Iris Xe Graphics; 16GB RAM; 1TB PCIe SSD; 70Wh battery (11h10min 1080p movie playback); 32.4 x 22.2 x 1.7cm; 1.62kg.

A great ultrabook for power users that need a second screen on the go. **Joel Burgess**

★★★★☆

$2,599 | dell.com/en-au

Dell G15

Is Dell's latest Intel based gaming laptop a gaming go getter or a mediocre money maker?

If Dell's long standing Alienware brand is a bit outside your budget then its home brand range of gaming laptops are an alternative that'll give you more frames per dollar. We've seen a number of decent entry-level gaming laptops emerge at just over the $1,000 mark in the past few years and you can still get the G15s with a 10th Gen Intel i5 and a GTX 1650 for around $1,100 for anyone on a particularly tight budget.

If you want the latest 11th Gen processors however, the new range of G15s start at the more mid-entry pricing of $1,699 ($1,444 on sale). For this you'll get a 15.6-inch full HD display, a Core i5-11400H CPU, 8GB of RAM and an Nvidia GTX 3050 GPU system with 512GB of PCIe storage. It's been many years since we tested a gaming laptop with only 8GB of RAM – it actually predates our testing database, so we can't actually confirm if consumers are getting shafted here. It is possible that 8GB is enough, considering the level at which you'll be gaming on a 3050, but it could also be a major bottleneck when playing something like *Cyberpunk 2077*, where 8GB memory is the minimum specification. Considering there's a handful of comparable gaming rigs with 16GB of RAM, faster screens and even better GPUs available for the same price, you'll probably want to go with something else here.

The next tier of G15 offers an i7-11800H CPU, 16GB of RAM and an RTX 3050 Ti for $2,199, and you can update this GPU to an RTX 3060 for an extra $400. There's a lot of competition around this price point so it's easy to find laptops with faster screens or more internal storage for a couple hundred dollars less.

Dell sent us the top end i7, 3060 model to test out and while this model is only a bit more expensive it will offer around 50 percent better graphical performance over the 3050 Ti unit. This is enough to push above 60fps on demanding titles at 1080p Ultra and will reach averages of about 100fps on less intensive titles like *F1 2021* on the same settings.

This performance is well balanced against the 15-inch 120Hz display which has good colour and a reasonable 250nit peak brightness. Unfortunately there's no G-Sync or FreeSync included so you'll have to expect a bit of screen tearing or big frame rate jumps.

When not gaming this CPU offers major generational bumps over the 10th generation i7 processors of between 19 to 66 percent. This processor will churn through demanding work tasks and should hold up to demanding photographic or modelling suites.

The 84Wh battery delivers a pretty standard four hours and 13 minutes under general working conditions and six hours and 13 minutes in 1080p movie playback.

	Dell G15	Acer Nitro 5
PCMark 10 - Overall (score)	6,647	5,200
Max CPU Temperature (C)	98	95
1080p movie playback (HH:MM)	06:13	06:22
HWBot x265 - 1080p (Ave fps)	57.689	34.692
3DMark Time Spy (score)	8,107	6,784
The Division 2 - 1080p Ultra (fps Av.)	76.00	61
CrystalDiskMark Read (MB/s)	2,824	1,880
CrystalDiskMark Write (MB/s)	1,411	1,718

Specifications
W10 Home 64-bit; 15.6-inch 120Hz display at 1,920 x 1,080 pixel resolution; Intel Core i7-11800H CPU; Nvidia GeForce RTX 3060 GPU; 16GB RAM; 512GB PCIe SSD; 84Wh battery (6h 13 min 1080p movie playback); 35.7 x 27.2 x 2.3cm; 2.4kg.

The G15 is a reasonable mid range gaming laptop with an above average price tag.

Joel Burgess

★★★½☆

$660 | anz.dynabook.com

Dynabook E10-S

Is the affordable Dynabook going to be dynamite for young students?

Dynabook, the Japanese laptop brand that was spun out of Toshiba in 2018, is continuing to expand its Australian range of devices with the new student focused E10-S. This new budget laptop is compact, durable and affordable… basically everything you'd be looking for if you needed a device for young kids to learn on.

The E10-S is runs a low-powered dual-core Intel Celeron N4020 CPU that operates in a frequency range of 1.1-2.8GHz. Paired with 4GB of RAM and integrated Intel UHD Graphics 600 you really shouldn' expect too much from this machine. Web browsing, document editing and very light browser-based games are about all this device can handle, but it's enough to achieve all you'd need to in most young learning environments.

The 11.5-inch screen is likely going to seem pretty pixelated and faded to anyone that has bought a laptop in the last five years, and unfortunately it isn't great even up against competition like Kogan's sub-$400 C500. While the 1,366 by 768 pixel display won't make video or web pages look super vibrant, the low 200nit peak brightness helps with battery life.

The device comes with an HD webcam, positioned at the top of the screen, and there's a dual microphone array and stereo sound, so you won't have to worry about it not being compatible for remote learning. The keyboard is actually surprisingly good too, offering nice key spacing and reasonable resistance and travel. The trackpad is soft and responsive.

The E10-S is a standard clamshell device, which means the hinge wont go past about 180 degrees, and the lack of touchscreen is disappointing compared to competitors. It's exterior is also entirely plastic, which is reasonable for this type of device. The 45Wh battery is a great feature of this unit. The less demanding screen and lightweight processor means you can get 11 hours and 16 minutes of work time or 12 hours and 20 minutes of 1080p movie playback.

The onboard storage is about as slow as you can get at 140/116MB/s read and write speeds. This is around what you'd expect from a hard disk drive, but it's on the slower end for entry level student laptops these days.

There's 802.11ac Wi-Fi, which is going to be fine for any student's needs, but the E10-S also comes with a Gigabit Ethernet connection to allow you to hardwire in Wi-Fi dead zones. Two USB 3.0 Type-A connections, an HDMI port, USB Type-C, and a MicroSD card reader all come included out of the box, which is a very versatile selection of connection options. Great to have, but potentially not essential in today's cloud-based computing landscape.

While we'd probably still opt for a Lenovo Ideapad Chromebook because of the modern screen and 2-in-1 capabilities, the Dynabook E10-S's generous battery life will mean that kids aren't caught out if they forget their charger.

	Dynabook E10-S	Kogan Atlas 11.6
PCMark 10 - Overall (score)	1,232	1,497
Geekbench 5 - Multi-core (score)	800	734
3DMark Fire Strike (score)	322	296
Geekbench 5 - OpenCL (score)	1,185	1,404
Battery life - 1080p video playback (h:min)	12:20	03:30
Peak CPU temperature (°C)	69	DNT
CrystalDiskMark Read (MB/s)	140	262
CrystalDiskMark Write (MB/s)	116	208

Specifications
Window 10 Pro 64-bit; 11.6-inch 200nit eDP screen at 1,366 x 768 pixel resolution; Dual-core Intel Celeron N4020 CPU; Intel UHD Graphics 600; 4GB RAM; 128GB eMMC storage; 45Wh battery (12h20min 1080p movie playback); 28.4 x 19.8 x 2cm; 1.15kg.

An affordable Windows student laptop with a generous 10 hour+ battery life. **Joel Burgess**

★★★★☆

$219 | pccasegear.com

Phanteks Eclipse P500a Airflow D-RGB

A big and handsome case that offers the potential to build just about anything inside.

We've long been fans of Phanteks cases, with them seeing regular appearances in our PC Builder section. Today we're looking at a great mid-ranged option, the Eclipse P500a Airflow D-RGB.

There are three P500a models, with the basic non-RGB model going for a very reasonable $159. Today though, we're looking at the up-tiered D-RGB model, which is available in black or white.

The D-RGB model adds a trio of 140mm D-RGB Phanteks-brand fans mounted at the front, as well as a D-RGB plug to connect to your motherboard. Most usefully – there's a button on the top that cycles through colours and modes – which is unbelievably convenient if your stars align and other RGB devices connect and can also be cycled this way. RGB software sucks, a dumb button is so much easier.

The P500a is all about airflow and capacity. The entire front panel is mesh, and the pre-mounted 140mm fans do a great job of moving large volumes of air through the case – and you can keep the fan speeds low thanks to the large fan area and unimpeded airflow. Up top there's ample room for either a 3x 120mm radiator or fan set, or a pair of 140mm fans. The rear exhaust doesn't ship with a fan, though it'll handle 120 or 140mm.

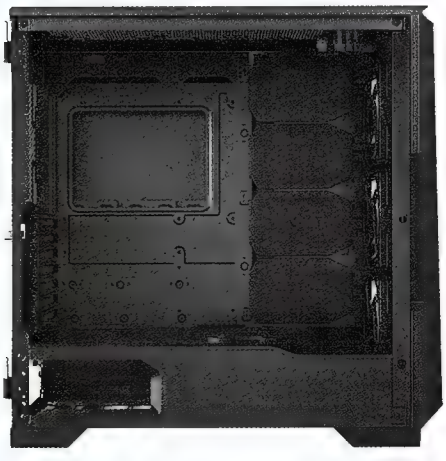
The tempered glass side panel is a wonderful hinged swinging door, and it lifts off its hinges easily and is held shut magnetically. Honestly it's my all-time favourite way to do this; so elegant and simple.

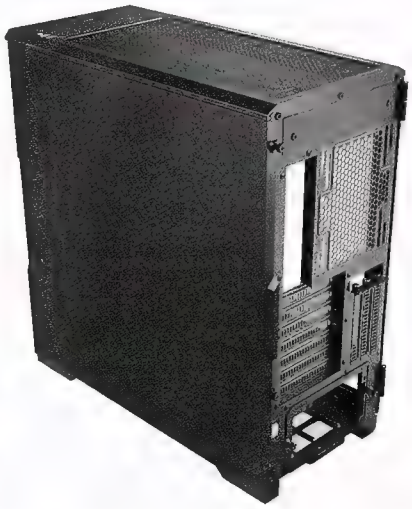
It's a large case, at 240 mm x 510 mm x 505 mm, and in fact has the capacity to include a second ITX-based motherboard, though you'll need to buy the optional ITX mounting bracket for that. For the rest of us it means a vast open space for easy building and good air movement.

Niceties include a GPU anti-sag bracket (there's an optional extra vertical GPU riser also available), sliding covers for cables routed to the rear as well as where PSU cables feed through. Top marks, too, to Phanteks for packaging all the screws in a proper compartmentalised screw tray!

There's bays or brackets for up to ten 3.5in drives, and three 2.5in SSDs. That's immense. Those brackets are easily removable for even more space. The rear area is unusually spacious, meaning no cable compression in that area.

It's what I'd describe as 'handsome'. Styled with just enough flair to give it a pleasing character, but with nothing silly or over the top. It's a large, somewhat heavy steel case in the old school tradition with a vast internal volume and capacity for just about any configuration you want, even a dual system. It would suit any creator wishing to pack in many drives and cards, or a gamer looking to have the space for even the largest GPU (maximum card length is 435mm), and configure for an airflow that keeps temps down even when running hot overclocked components.





A traditional case with well thought out quality-of-life features and absolutely massive room for any config. **Ben Mansill**

★★★★½

$1,599 | benq.com/en-au

Benq Mobiuz EX3415R

Is Benq's latest 34-inch ultrawide the perfect gaming and business battlestation?

While pro gamers are going to use flat, small 16-by-9 screens because they're the fastest, most colour accurate and consistent screens around, anyone that actually wants to enjoy games, ultrawide curved displays are where it's at.

Benq's Mobiuz EX3415R is a 34-inch 21-by-9 ultrawide gaming display that is big enough to make you forget any ambitions you had for multi-screen setups. With a curvature of 1900R this screen is flat enough to keep everything nicely proportioned while still feeling like it wraps into your peripherals to give you a giant and consistent viewing experience. The EX3415R sits at the higher end of Ultrawide monitor resolutions with a 3,440 by 1,440 pixel screen that offers a great balance between clarity and GPU processor demand.

There's no doubt you'll want a solid GPU to run games on this ultrawide monitor. You're not just stepping up from 1080p gaming to 1440p, but you're also adding enough horizontal pixels to make it closer to 4K frame rates. While you'll get around 60fps averages using 21:9 1440p Ultra settings on most games from a Nvidia GeForce RTX 2080, more demanding titles like *Cyberpunk 2077* will only just be playable with this GPU. So, you're probably going to want to pair this with an equivalent 30 series GPU like a Nvidia GeForce RTX 3060 Ti or better to get the most out of it. On less demanding titles like *F1 2021*, frame rates using these GPUs start to get above 60fps and begin making use of the EX3415R's 144Hz refresh rate.

The EX3415R includes AMD FreeSync Premium certification, which means Both 20-series and newer Nvidia cards, and AMD GPUs will be able to tap into this monitor's 120Hz certified screen-tear-free experience. It also offers low framerate compensation that'll repeat frames to sync with your monitor when frame rates dip below its specified refresh rate. Interestingly, Benq didn't opt for AMD's FreeSync Premium pro tier, which offers low latency when the monitor is using HDR colour. This is an interesting choice considering the monitor has 98 percent DCI-P3 colour coverage and has been independently certified as VESA DisplayHDR 400 compliant.

Essentially what all this means is that while the colour accuracy is excellent in normal viewing modes, and is close enough to professional editing specs to be genuinely useful to professionals, this monitor may lose a little fidelity when gaming at high refresh rates. Instead, BenQ includes HDRi emulation viewing modes that attempt to manufacture HDR-like colour from SDR while gaming at high framerates. This might be a downside for professionals, but the vibrant and saturated colours will not look overly different for anyone simply wanting immersion.

The EX3415R takes a slightly different approach with speakers by including a decent set of 2.1 channel 5W speakers in a front facing soundbar at the bottom edge of the screen. These work well enough to mean you can ditch any desktop speakers.

Rather than on screen controls the EX3415R comes with a remote that lets you access the extensive suite of menu options, which shouldn't leave you wanting any extra display modes for work or play.

Specifications
34-inch IPS display at 3440 x1440 pixels; 400nit peak brightness; 1ms (MPRT) response time; Vesa Display HDR 400; 98% DCI-P3 colour gamut; Delta E < 3; 1000:1 native contrast; LED backlit; 2 x HDMI 2.0, 1 x DP 1.4, 2 x USB 3.0; 2.1 channel (2 x 2W + 1 x 5W woofer); 52.5x81.2x27cm; 12.6kg.

"There's no doubt you'll want a solid GPU to run games on this ultrawide monitor. You're not just stepping up from 1080p gaming to 1440p, but you're also adding enough horizontal pixels to make it closer to 4K frame rates."

An enviable, colour-accurate 34-inch 21:9 gaming monitor that's pricey, even for an ultrawide. **Joel Burgess**

★★★★☆

$679 | www.msi.com

MSI Spatium M480 2TB M.2 NVMe SSD

MSI goes all in with a high performance SSD offering.

MSI is well known for its PC components, laptops, and systems. Now it's adding another product category to its portfolio with the release of its Spatium SSD series. In fact, other than CPUs and memory, MSI now offer a complete catalogue of PC components. Here we have the flagship M480 SSD in for review. It's joined by its more affordable sibling, the M470, which we're also reviewing this issue. Can MSI challenge the established leaders in the SSD marketplace?

Like almost all retail M.2 drives, the Spatium 480 is 2280 (80mm length) M.2 drive. It makes use of Micron 96-Layer TLC NAND and a Phison PS5018-E18 controller. It's got 2GB of DDR4 DRAM onboard. MSI claims sequential read and write speeds of 7,000/6,800 MB/s, which compares to the 7,000/5,500 MB/s for the 1TB model. The M480 comes with a chunky bundled heatsink, providing welcome installation flexibility. The 2TB model comes with a 1,400 TBW endurance rating to go with a five-year warranty. Curiously, the cheaper 1TB M470 features a 1,600 TBW rating, not that a regular user will ever get close to those levels. The MSI comes with the usual features like Trim support and S.M.A.R.T. reporting, and it also offers AES256 encryption, which is welcome, especially when some manufacturers are omitting it.

Special mention has to go to MSI's packaging and presentation, which is very impressive. If you're going to drop close to $700 on an SSD, you want something that looks the part, and MSI got it right. It's a small thing in the grand scheme of things, but as SSDs often have little to differentiate between them, small things matter.

When it comes to performance, the Spatium M480 easily matches its rated sequential read and write speeds, in fact returning the fastest sequential write speeds we've seen from any drive to date. It's not far behind in read speeds either. The M480 is very close to the similar Phison E18-equipped Teamgroup A440 Cardea. The Spatium M480 delivers strong 4K random read performance and IOPS, only trailing the mighty Samsung 980 Pro and WD SN850. Its random write performance is even better, though not as important in a consumer environment.

We ran the M480 with its optional heatsink attached, and we were very pleased with the results, with a maximum recorded temperature of 56c. This makes it one of the coolest PCIe 4.0 drives we've tested.

At the time of writing, the Spatium M480 2TB was priced at $679. That makes it one of the more expensive Phison E18 drives. Though it's a little cheaper than the Team A440 and WD SN850 drives, it's more than Samsung's formidable 980 Pro and that's its biggest Achilles heel. We feel the SSD needs to drop under the 980 Pro's price if it's to really appeal to the market. Pricing is flexible though, and in the months ahead, it may become a compelling option indeed. It's got great write performance, it blends form and functionality and, overall, it's a solid SSD entry by MSI. Pricing aside, there's nothing stopping MSI from becoming a serious player in the SSD space.

Specifications
MSI Spatium M480 2TB M.2 NVMe SSD; PCIe 4.0 x4; Phison PS5018-E18 controller; Micron 96L TLC NAND; 7,000 MB/s sustained read, 6,800 MB/s sustained write, 650K/700K read/write IOPS; 1400 TBW endurance; Five year warranty.

"When it comes to performance, the Spatium M480 easily matches its rated sequential read and write speeds, in fact returning the fastest sequential write speeds we've seen from any drive to date."

MSI enters the SSD market with a strong competitor, though it needs a price drop if it's to entice buyers away from the big names.

Chris Szewczyk

★★★★☆

$279 | www.msi.com

MSI Spatium M470 1TB M.2 NVMe SSD

One to watch for if you value reliability.

Along with the high-end MSI Spatium M480 comes a more value-oriented option, the M470. Where the M480 goes for all out performance, the M470 is more of a mainstream offering, giving away a bit of sequential performance without losing much in the way of real world performance or responsiveness.

Like its big brother, the M470 is a standard form factor 2280 (80mm length) M.2 drive. It makes use of Toshiba's 96-Layer TLC NAND and interestingly, Phison's first generation PS5016-E16 controller. It also includes a 1GB DRAM buffer. The 1TB M470 we have in our labs for review is rated for 5,000/4,400 MB/s sequential read and write speeds. The M470 doesn't come with the optional heatsink of its M480 sibling. PCIe 4.0 drives can run hot so you'll need to install it under a motherboard heatsink or have good case airflow to prevent it from throttling if you punish it for extended periods.

One of the most interesting characteristics of the 1TB M470 is its endurance rating of 1,600 TBW, which is stunning for a 1TB drive. Samsung and WD are well behind here. It's a number you're more likely to see on a 2TB drive. If reliability is at the top of your list of purchase criteria, this is a drive you should seriously consider. The Spatium M470 lacks the AES256 hardware encryption capability of its M480 stablemate, but this isn't too much of an omission for a consumer-oriented drive. There is OPAL 2.0 support for software encryption.

The Spatium M470's sequential performance testing almost perfectly matched its official specification. At 5GB/s it's not an ultimate PCIe 4.0 speed demon, but even if you find yourself transferring multiple gigabytes at a time, would you notice an extra second or two here or there? The M470 is also a step behind the performance leaders when it comes to random read performance. It's ahead of early generation PCIe 4.0 drives though. And, like the M480, the M470's random write performance and IOPS is very good, much faster than early generation PCIe 4.0 drives with the same controller. When you combine strong write performance with its endurance rating, the M470 is a solid choice for a user looking for a drive to really thrash. Well done MSI.

As the real world performance of SSDs converge, value weighs heavily. The Spatium M470 has an RRP of $279, which places it under WD and Samsung drives, but also below competitors like the Corsair MP600. If you're on a tight budget then there's still some great value and performance to be had from PCIe 3.0 drives, but we can expect those to disappear from the market as PCIe 4.0 support trickles down.

The MSI Spatium M470 proves itself as a capable allrounder. It's not smashing out records but it's the kind of drive that will function very well as storage for a game library or, thanks to that incredible endurance rating, as a scratch disk for users managing large data sets that frequently write to disk. MSI, with the M470 and M480, might not have the vertical integration advantage of Samsung, WD, or Micron, but we're sure there are other SSD manufacturers that will be a bit worried about MSI's challengers in this competitive space. If it was a few dollars cheaper, MSI could really shake things up.

The M470 features a stunning endurance rating, making it a good option for users who write to disk a lot. **Chris Szewczyk**

★★★★☆

	Samsung 980 Pro 500GB	Western Digital Black SN850 1TB	TeamGroup Cardea A440 2TB	MSI Spatium M470 1TB	MSI Spatium M480 2TB
Crystal Disk Mark Sequential Read MB/s	6,785	7,071	7,166	5,001	7,137
Sequential Write MB/s	4,869	5,229	6,764	4437	6,876
Anvil Storage Utilities 4K Random Read - MB/s Queue Depth 1	85.33	82.42	68.80	59.90	68.47
Anvil Storage Utilities 4K Random Read - MB/s Queue Depth 4	339.21	300.22	268.15	236.10	273.51
Anvil Storage Utilities 4K Random Write - MB/s Queue Depth 1	211.42	255.17	270.62	253.30	272.57
Anvil Storage Utilities 4K Random Write - MB/s Queue Depth 4	746.64	879.44	905.60	903.10	977.30
Anvil Storage Utilities 4K Random Read - IOPS Queue Depth 1	21,845	21,099	17,612	15,353	17,783
Anvil Storage Utilities 4K Random Read - IOPS Queue Depth 4	87,018	76,855	68,645	60,455	70,018
Anvil Storage Utilities 4K Random Write - IOPS Queue Depth 1	54,124	65,322	69,279	64,864	69,778
Anvil Storage Utilities 4K Random Write - IOPS Queue Depth 4	191,140	225,135	231,833	231,211	250,188
Internal File Copy 30GB of mixed file sizes - Time (secs)	26	27	27	31	27
Final Fantasy XIV: Stormbringers Scene Loading - Time (secs)	7.619	7.680	8.340	8.010	8.109

$549 | www.amd.com

AMD Ryzen 7 5700G

The APU makes a welcome return.

AMD's Ryzen 5000 CPUs have been in high demand ever since they launched, but apart from the 5600X, the more affordable end of the market has been neglected. That's beginning to change with the welcome return of the APU, which finally combine graphics capabilities with the Zen 3 architecture. The new Cezanne family of APUs is led by the Ryzen 7 5700G we have for review. It is joined by the hex-core Ryzen 5 5600G. They are the first new APUs in the retail market since the release of the Zen+-based 3200G and 3400G in mid-2019. The 5600G and 5700G can't be considered budget parts, though we do hope to see the quad core 5300G released to better compete with Intel's strong 11th Generation i5's.

The promise of Zen 3 cores and best-in-class integrated graphics has been eagerly anticipated. Non-gamers appreciate having display capabilities without having to cough up needless expense for a discrete GPU, while casual gamers will find they can easily play older or less demanding titles, perhaps while waiting for discrete GPU prices to normalise.

The 5700G is a Zen 3-based processor with a 7nm 180mm2 monolithic die, with eight cores and 16 threads. It has a base frequency of 3.8GHz and a boost frequency of 4.6GHz. It has a very desirable 65W TDP. But it's not a 5800X with graphics bolted on. You lose half of the L3 cache (16MB vs the 32MB of the 5800X) and, importantly, PCIe 4.0 support. You do get AMD's Wraith Stealth cooler, which is a nice value add.

"The promise of Zen 3 cores and best-in-class integrated graphics has been eagerly anticipated. Non-gamers appreciate having display capabilities without having to cough up needless expense for a discrete GPU, while casual gamers will find they can easily play older or less demanding titles, perhaps while waiting for discrete GPU prices to normalise."

The integrated graphics is surprisingly still based on the ageing Vega architecture, with eight compute units operating at 2.0GHz. Vega graphics benefit from faster memory, so if you plan to game, make sure you spend a few extra dollars on a 3600MHz-class kit.

Compared to the 5800X, the smaller cache and lower frequency count against it, but compared to the 3700X, it's a big step forward. We don't have Intel's 11700K to compare against, but notably, the 5700G matches or beats an eight core 9900K and therefore a 10700K, both of which remain popular CPUs. When it comes to integrated graphics performance, there's the 5700G and then there's daylight. 1080p gaming with low settings is viable even with demanding titles like *Metro Exodus*. Intel's 11th Gen Xe graphics cannot compete.

Power efficiency is very impressive. We saw a peak power consumption of 77w. The likes of the 11700K can use three times that! It also means that even a modest air cooler won't be stressed at all.

The 5700G is a very good CPU, but it needs to be considered in context. The 5800X is faster, with more cache and PCIe 4.0, while Intel's i5 Rocket Lake processors are affordable and excellent for gaming with a discrete GPU. But, there are many strengths. It's very good at heavy multitasking and it's well-suited to a low power HTPC or SFF system. Then there's best-in-class IGP. If you're a casual gamer or looking for something with integrated graphics to tide you over until the GPU market returns to normal, then all things considered, the 5700G is a very good all-rounder.

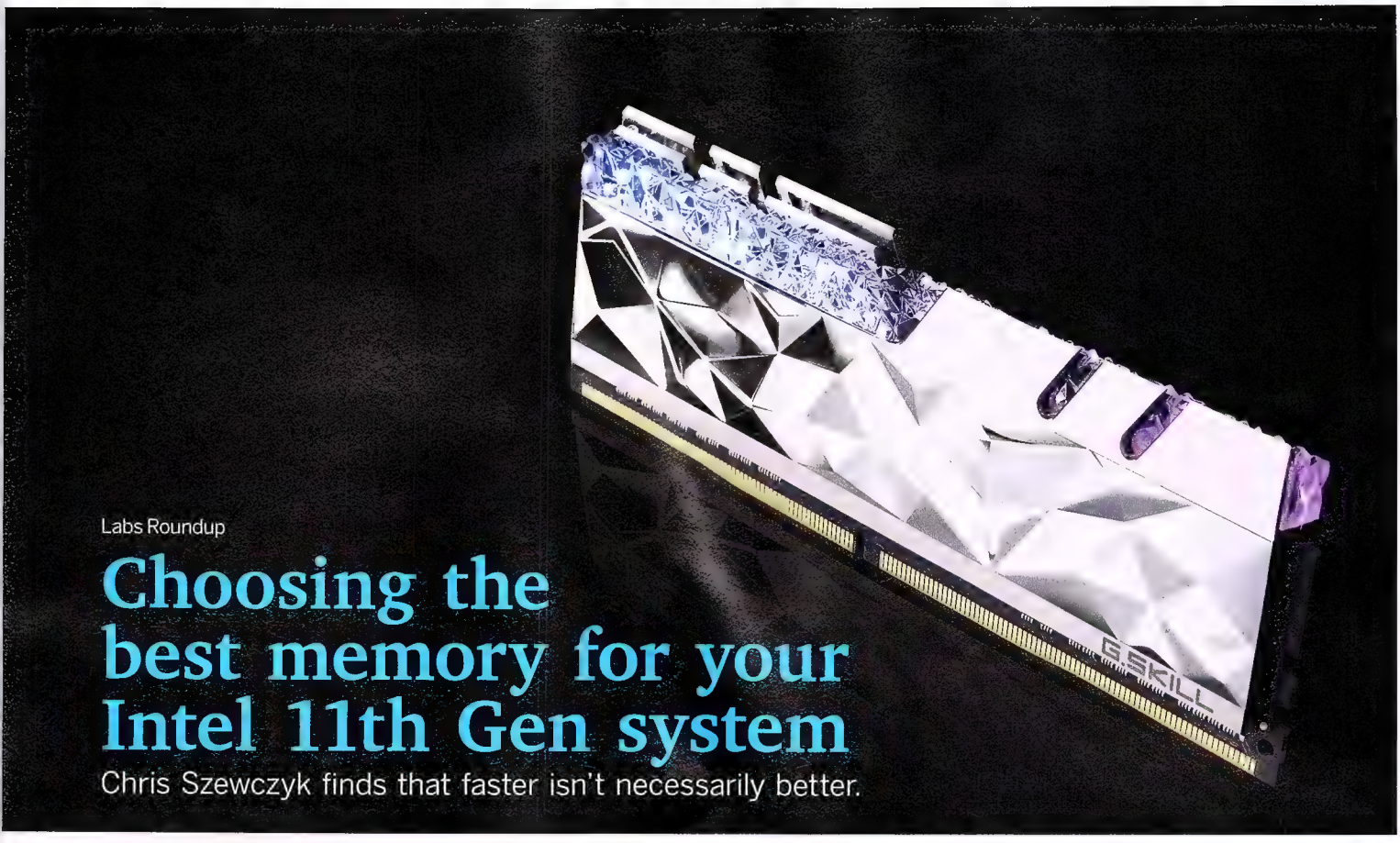
The fastest ever integrated graphics combined with eight Zen 3 cores and a 65W TDP make this a fantastic all rounder CPU. **Chris Szewczyk**

★★★★½

	AMD Ryzen 7 5700G	AMD Ryzen 7 5800X	AMD Ryzen 5 3400G	AMD Ryzen 7 3700X	Intel Core i9-9900K	Intel Core i5-11600K
Cinebench 20 - Multi thread Score	5,468	6,083	1,897	4,806	4,846	4,205
Cinebench 20 - Single thread Score	580	617	391	500	490	582
Blender 2.93 BMW Render - Time (seconds) Lower is better	180.0	162.1	430.9	189.4	179.5	228.2
3DMark TimeSpy Extreme - Overall score	7,883	8,238	5,686	7,787	7,976	7,660
3DMark TimeSpy Extreme - CPU Score	4,702	5,640	1,859	4,547	4,872	4,305
Metro: Exodus - 1080p, Ultra, DX12, Avg FPS	119.6	127	105.2	108.1	119.4	123.5

Specifications

AMD Ryzen 7 5700G; Socket AM4; 8core/16thread; 3.8GHz base/4.6GHz boost clock; 16MB L3 cache; RX Vega 8 Graphics. 8 Compute Units; Supports DDR4-3200; 65W TDP.



Labs Roundup

Choosing the best memory for your Intel 11th Gen system

Chris Szewczyk finds that faster isn't necessarily better.

Are you considering an upgrade to an Intel 11th Gen system and wondering what kind of memory to go for? Choosing the best 11th Gen isn't as cut and dried as it was with 10th Gen. We've got four kits in for review, all of which are very good in their own way. Though all of the kits can be used with any AMD or Intel DDR4 system, we're focusing on 11th Gen for this roundup. The reason is the introduction of a new memory controller divider, or Gear 1 and Gear 2, which heavily influences how memory behaves on a Rocket Lake system.

Unlike previous generations, Rocket Lake introduces an option to set the memory controller at half the speed of the memory clock, or 1:2. Intel refers to 1:1 mode as Gear 1 and 1:2 mode as Gear 2. For example, at DDR4-3600 with Gear 1, the memory and memory controller are both running at 1800MHz (remember that DDR refers to double data rate). When Gear 2 is selected, the memory speed would remain at 1800MHz while the memory controller drops to 800MHz. That drop in memory controller speed delivers a significant latency hit.

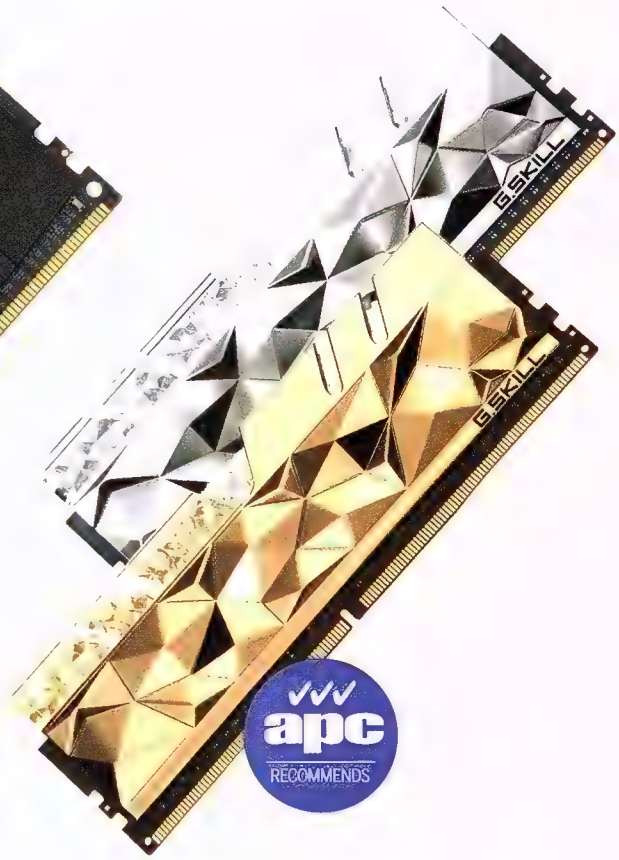
Gear 1 runs well up to about 1800 MHz, which means that an affordable DDR4-3600 kit is optimal for almost all users. But, faster kits have their place still. Some applications prefer higher bandwidth and if you can run your memory in the upper 4000MHz range, you'll mostly offset the Gear 2 latency penalty. Are the really expensive kits worth it, though? Mostly no. Running such kits at their default XMP settings is a waste. Those kits are for tweakers. If you want to extract the maximum from your equally high spec system, there's definitely a place for them though.

Read on as we take a look at a variety of DDR4 memory kits, some of which may be remembered as being among the very best DDR4 kits ever.

	Crucial Ballistix RGB DDR4-3600 2x16GB 16-18-18-38	Teamgroup Xtreem ARGB DDR4-3600 2x16GB 14-15-15-35	G.Skill Trident Z Royal Elite DDR4-4000 2x8GB 14-15-15-35	Kingston Fury Renegade RGB DDR4-4600 2x8GB 19-26-26-46	Reference DDR4-3200 16-18-18-36
X264 v5.0 Video Encoding - Pass 2 Avg FPS	48.07	48.35	47.85	48.20	48.1
Cinebench 20 - Multi-thread Score	5,987	5,993	5,999	5,966	5,962
Cinebench 20 - Single-thread Score	636	635	633	634	622
Blender 2.93 BMW Render - Time (seconds) Lower is better	153.6	153.2	153.4	153.4	153.4
7Zip 19.00 - Million Instruction per second	81,957	89,514	79,948	80,935	73,673
POV-Ray - Ray Tracing - Pixels Per Second	6,334	6,337	6,357	6,346	6,339
Handbrake Video Encoding - 4K 10-Bit HEVC to 1080p FPS	74.0	77.5	75.8	77.2	70.0
AIDA64 - Read MB/s	52,692	53,371	60,088	65,278	48,141
AIDA64 - Write MB/s	50,997	53,752	57,907	65,809	47,109
AIDA64 - Copy MB/s	51,995	56,038	56,448	62,070	46,839
AIDA64 - Latency ns	49.3	45.0	51.8	53.0	51.6

Test Setup

CPU: Intel Core i9-11900K, MB: Z590 Aorus, Tachyon, GPU: MSI RTX 3080 Gaming X Trio, Power Supply: Corsair AX1000. Storage: 2TB Adata XPG Gammix S70, Case: Thermaltake Core P8.



$350 | www.crucial.com

Crucial Ballistix RGB DDR4-3600

Hitting the sweet spot.

The Crucial Ballistix RGB 2x16GB kit at DDR4-3600 with 16-18-18-38 timings can be considered a good 'sweet spot' kit. It's not all that much more expensive than a mainstream DDR4-3200 kit, and there's a slightly cheaper non-RGB version if you prefer a discrete look.

Speaking of RGB, the Ballistix kit is very bright, at least compared to the Kingston kit, and the colours are especially vibrant and accurate. The heatspreaders do feel a little on the flimsy side – not that you need much cooling on a modern DDR4 kit, though.

The Crucial performs well in the benchmark results. As DDR4-3600 sits near the upper limit of the Gear 1 ratio, you get the benefit of that low latency setting without the hit the G.Skill kit takes at Gear 2 and DDR4-4000. The kit also has some decent OC headroom, but unless a kit can hit the 4600MHz+ range, OC delivers little to no benefit, though it's worth a go in a 10th Gen or older system.

For most users, including creators and gamers, a good 32GB DDR4-3600 kit like the Crucial Ballistix kit is perfectly suitable for every kind of workload. It's widely compatible on any modern system and it requires the standard 1.35v. It does have some pretty tough price competition, but make sure you aren't getting an inferior memory IC with looser timings if you go for a cheaper kit. Of the kits we're testing here, however, the Crucial is streets ahead when it comes to bang for buck. It's a good 32GB kit that will do a good job, and if you love RGB, it's even better.

Specifications
Crucial Ballistix RGB; 32GB (2x16GB); DDR4-3600 16-18-18-38 at 1.35 V; XMP 2.0 Support; Limited Lifetime Warranty.

3600MHz at CL16 is right in the price/performance sweet spot for a fast 11th Gen system.

★★★★½

$509 | www.gskill.com

G.Skill Trident Z Royal Elite DDR4-4000

An overclockers' favourite.

Here's a kit! DDR4-4000 at 14-15-15-35 timings is something that only serious overclockers would attempt just a few years ago, and now here it is at stock. This kit makes use of highly binned Samsung B-Die, which is still regarded as the best memory IC. The kit's silver or gold mirror finish and crystalline RGB light bar is definitely attention grabbing, though some might see it as a bit over the top, if not garish.

Running this kit at XMP is a crime, and it shows in the benchmark results. DDR4-4000 is about the worst speed you can run on 11th Gen due to being forced to set Gear 2. A kit like this can run in the DDR4-4800 range where its true performance edge will show up. Alternatively, a regular gamer looking for optimal performance can consider running this kit at something like DDR4-3600 C12. Pretty crazy right?

Does a kit like the G.Skill 4000 C14 make a lot of sense? To 95 percent of users it doesn't. And 90 percent of that 95 percent will probably be happy with a 3200MHz kit. But, the five percent of PC enthusiasts looking to extract the absolute maximum from their system will consider the G.Skill 4000 C14 kit to be among the very best DDR4 kits on the market. That means it may well end up considered among the best overclocking DDR4 kits of all time. You do have to pay for it though. It's not practical and there's not a lot of need for such a kit, but those who love to tweak will sing its praises. But please do *not* leave it languishing at its XMP setting on an 11th Gen system!

Specifications
G.Skill Trident Z Royal; 16GB (2x8GB); DDR4-4000 14-15-15-35 at 1.55 V; XMP 2.0 Support; Limited Lifetime Warranty.

This amazingly flexible kit can do high frequency or tight timings, or both! But such a kit doesn't come cheap.

★★★★☆

$529 | www.teamgroupinc.com

Teamgroup T-Force Xtreem ARGB DDR4-3600

An awesome set and forget 11th memory kit.

If the Crucial kit sits in the performance sweet spot, then the Team Xtreem ARGB kit also sits there, but with an even sweeter cherry on top. At DDR4-3600 and 14-15-15-35 timings, this is where you should be looking for the optimal blend of Gear 1 low latency performance, 32GB capacity, and reasonable price; though its quite a jump from mainstream CL16 to CL18 3600 kits.

The subtle white lighting looks amazing, though it might not match every build. It's built with the Samsung B-Die IC, which remain the best DDR4 chips. It's also a dual rank kit, which will give it a couple of extra percent of performance here and there. We tried a quick and dirty OC, but as expected it couldn't match the much higher binned G.Skill kit, though there is scope to tighten the timings further at 3600.

The benchmark results reveal that the combination of Gear 1, 3600MHz and tight timings provides a truly optimal setting for an 11th Gen system. Even the Kingston kit at 1000MHz higher only just begins to overcome the Gear 2 and inferior timing latency penalty. Whether the extra cost is worth it over a kit like the Crucial or any other mainstream 3200MHz or 3600MHz kit will depend on your partnering components. Do you run an 11900K and RTX 3080 Ti? Then yes, it's worth it.

The Team ARGB kit is one of the best set-and-forget kits on the market. 32GB of DDR4-3600 at CL 14 offers a great level of performance. There's overclocking headroom too (on the right system, that is) and with a 32GB capacity, it will probably be the last DDR4 kit you'll ever need.

Specifications
Teamgroup Xtreem ARGB White; 32GB (2x16GB); DDR4-3600 14-15-15-35 at 1.45 V; XMP 2.0 Support; Limited Lifetime Warranty.

One of the best set and forget kits on the market.

★★★★½

$549 | www.kingston.com

Kingston Fury Renegade RGB DDR4-4600

Looking for DDR5 speeds?

Now here's something a bit different. 11th Gen systems can clock memory higher than ever before, even well above 5000MHz in some cases. The Kingston Fury Renegade runs at a slightly saner 4600MHz at 1.5V with 19-26-26-46 timings. This puts it at a level where the Gear 2 latency penalty is mostly offset. Though whether a kit like this is suitable for you will be task dependent.

The Renegade kit is very solidly built, with strong and hefty heatspreaders and a rather low intensity RGB implementation compared to other kits. It makes use of the Hynix DJR IC, which are the chips you'll have seen used for many world record speed attempts.

Running it at its XMP setting showed it to be competitive with the kits running at the Gear 1 setting, but this isn't a kit you should leave running at default. Playing with clocks and timings can yield some worthy performance gains. We were able to hit 5000MHz for the first time ever, but it required levels of IMC voltages that we weren't comfortable with. This kit, like the G. Skill kit, is one for the tweakers or users of applications that can make use of the very high bandwidth on offer. Look at those AIDA64 results for example.

The weakness of the Renegade kit is it pricing. We'd expect it to fall once the semiconductor market returns to normal but at time of writing it was a sky high $549, which for a 2x8Gb kit is pretty hard to stomach. Kingston sell plenty of kits that offer better value. It's a good fun kit but at this price its one for hardcore overclockers only.

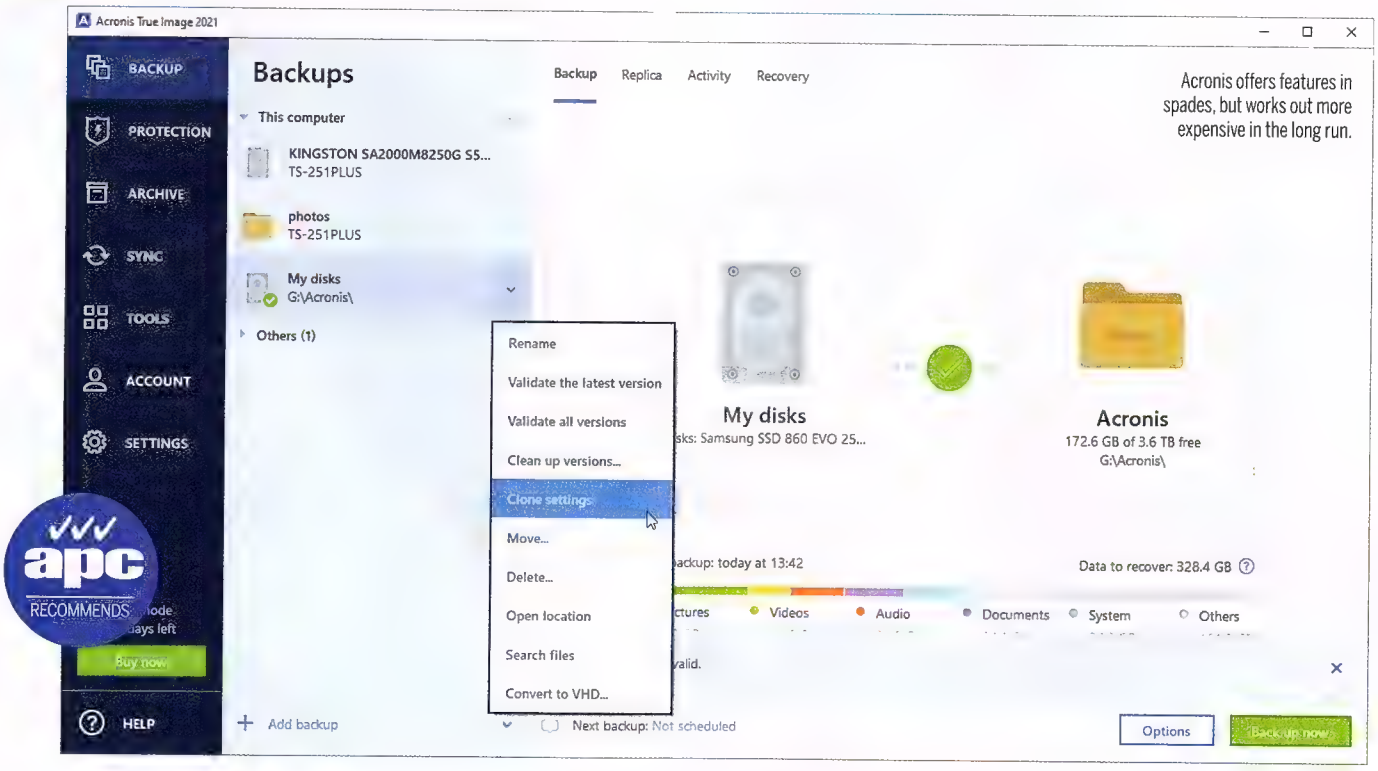
Specifications
Kingston Fury Renegade RGB; 16GB (2x8GB); DDR4-4600 19-26-26-46 at 1.5 V; XMP 2.0 Support; Limited Lifetime Warranty.

The Kingston Renegade is a good fun OC kit but its price is hard to justify.

★★★½☆

SOFTWARE

APPS FOR ALL YOUR PLATFORMS



ACRONIS TRUEIMAGE 2021 $69.99/year for one device | http://acronis.com MACRIUM REFLECT HOME 8 US$69.95 for 1 PC | http://macrium.com

Acronis vs. Macrium

Which drive-imaging app offers better protection?

Everyone needs a reliable backup tool, and as we outline in this issue's main feature, that should include a full drive image of your entire system, giving you the ability to restore your PC to working order with minimal disruption in the event of disaster. This issue, we're pitting two drive-imaging tools against each other: Macrium Reflect 8 Home Edition is the paid-for version of our favorite free drive-imaging tool, while Acronis TrueImage 2021 is a long-established and trusted heavyweight.

But do you even need to pay for a drive-imaging tool? Macrium Reflect Free has protected our PCs for years, but there are some niggles that both the Home edition and Acronis resolve, the main one being support for incremental backups. These make daily (and even intra-daily) backups practical thanks to the fact they're smaller and faster than differential backups.

Both paid-for tools support password-protected encrypted drive images for greater security, too, as well as protection against ransomware, which could infect your backups. Both also allow you to back up individual files and folders. But which one offers the most bang for your buck?

Acronis TrueImage offers you a choice of tiers, while Macrium Reflect 8 Home Edition is a single product. Acronis adopts subscription-based pricing, starting at $46.99 per year for the Essential tier. This entitles you to the next major release – Acronis TrueImage 2022 is imminent. It also offers two additional tiers, both of which come with added anti-malware protection (nothing to write home about, but reasonably solid aside from a weakness against browser phishing), alongside cloud storage to let you to store backups off-site.

Upgrading to cloud storage may seem like a no-brainer, but while the premiums are reasonably competitive – $125.99 a year for 500GB or $174.99 a year for 5TB of cloud storage – there's a major catch: Unless you have a super-fast connection, it'll take forever to upload a full drive image. Compared to other cloud providers, Acronis isn't the quickest either.

Macrium Reflect offers no option to back up to the cloud or any anti-malware components, but this is reflected in its price: a one-off US$69.99 for version 8. Macrium Reflect 7 debuted in early 2017, so version 8 will probably last you several years – and naturally covers all 8.x updates, which are likely to contain several new features if the previous version's life cycle is anything to go by. If you're looking to protect your entire household, a four-PC license for US$139.95 is also available.

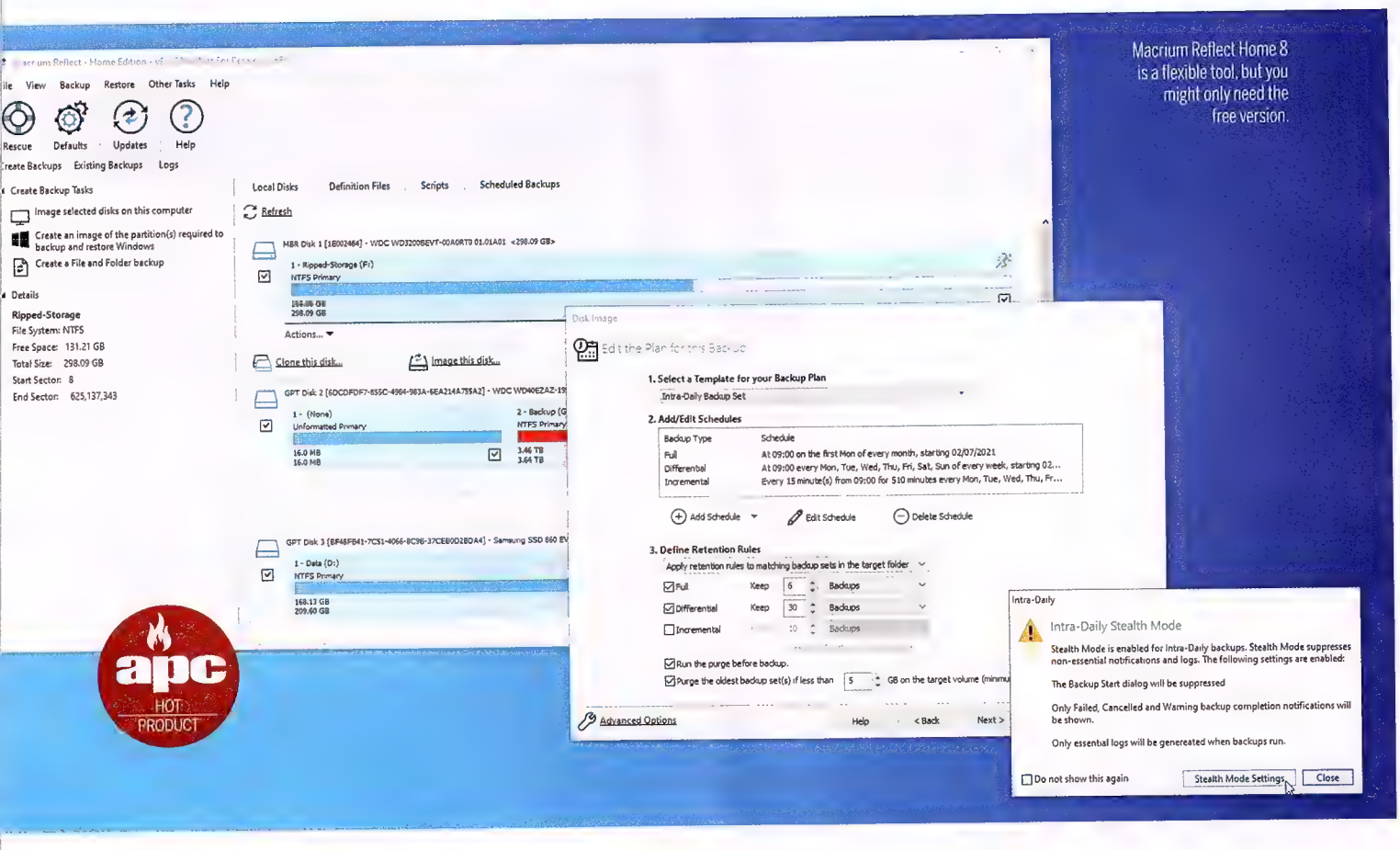
How they compare

Acronis TrueImage's interface feels like an attempt to pitch itself to a less technical audience, illustrated perfectly by the backup wizard. At first glance, you simply choose your source and destination, then click "Back up now." In reality, you need to spend time on the multi-tabbed "Options" screen, setting up both fundamentals such as scheduling and backup type, along with optional tweaks, most of which are buried away under the "Advanced" tab.

Macrium invites you to choose a backup type from its main screen: image selected disks, image system partitions, or files and folders. From here you confirm your selection and choose a destination, then set your schedule before reviewing your settings and clicking "Backup." Again, "optional" extras are hidden behind an "Advanced" dialog, and it's here we administer a slap on the wrist to both products for requiring you to check a well-hidden box to automatically verify backups after they've been completed.

We tested both by performing a full backup of our system and data partitions – combined size 350GB. In some ways, raw performance isn't important, so long as the backup can complete in the background without affecting your PC usage. Macrium took around 40 minutes

©Acronis



to back up both drives locally to a single 261GB file – a separate progress window provides all the detail you need, plus an option to adjust CPU priority to make it quicker or less intrusive while you get on with other tasks.

Acronis's progress indicator is less verbose, but it displays a breakdown of file types across your backup after completion, along with an easily accessible summary. This reveals it came in smaller at 218GB, taking 57 minutes. In its defense, Acronis sets its CPU priority to low by default, but you can't change this during the backup.

Neither tool had a noticeable effect on performance, which means you can happily get on with other things, making backup speed less important, doubly so given that subsequent differential and incremental backups are smaller and much quicker.

Restoring from backups is straightforward enough, and both apps offer rescue media creation tools that are WinPE-based, so easy to use in the event of disaster. You can also recover individual files by mounting your images as virtual drives in File Explorer. Acronis goes further: If you back up to the cloud, you can access your files through an online portal in your web browser or via a mobile app.

Both programs can also clone drives – perfect when migrating to a new SSD, for example – and both support converting images for use as virtual machines. However, while both support Hyper-V format, Macrium 8 gets the jump on Acronis by adding support for VirtualBox.

Despite this, Acronis strikes back by offering additional tools and perks to broaden its appeal. Additional options include archiving large files to the cloud, system cleanup, and encrypted storage. Its mobile apps also do more than simply provide access to the online dashboard – you can back up your phone to your cloud storage or to your PC via your home Wi-Fi.

In contrast, Macrium focuses on polishing its core offering: Version 8's headline new feature allows you to back up as often as every 15 minutes using its Intra-Daily Backups (Acronis supports hourly backups in similar fashion). There's no magic new tech at play – the feature uses incremental backups wrapped up in a new scheduled option with some context-sensitive options (such as suppressing notifications to avoid being plagued by 15-minute reminders) to transform Macrium into a reliable snapshot tool that renders System Restore redundant.

So, which drive-imaging tool should you choose? Both provide an excellent service backing up your system, so you might want to choose based on feature set. Here, Acronis wins hands down, but all is not quite what it seems. Cloud backups are nice in theory, but imaging to the cloud is slow and ponderous. Another black mark against it is the need to pay an annual subscription for even just the basic product.

Macrium lacks those bonus features, but offers a solid, reliable – and versatile – way to back up all or part of your PC, plus you get a lifetime license for your money. The free version has served us well for years, but the additional features present in the Home edition – in particular support for incremental backups – make this an irresistible choice.

Acronis TrueImage 2021

Wide range of backup options; lots of extra tools; cloud options.

★★★★☆

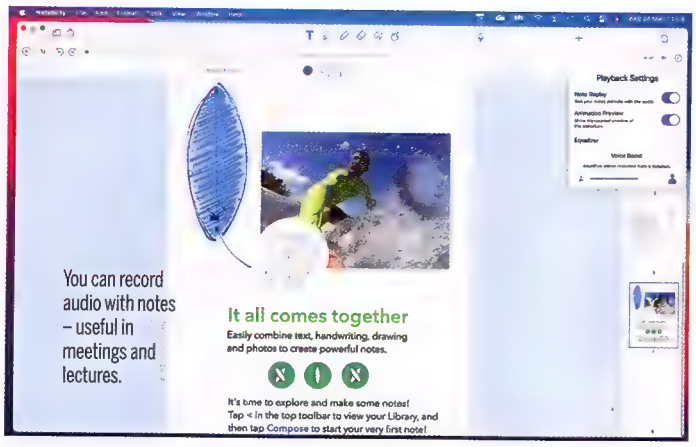
Macrium Reflect Home 8

Solid, reliable, and fast; no-nonsense user interface; flexible backup options.

Nick Peers

★★★★½

© Macrium


You can record audio with notes – useful in meetings and lectures.
It all comes together
Easily combine text, handwriting, drawing and photos to create powerful notes.
It's time to explore and make some notes!
Tap < in the top toolbar to view your Library, and then tap Compose to start your very first note!

macOS 10.15 or later | $13.99 (IAPs) | gingerlabs.com

Notability

Share and sync with iOS devices.

Notability is one of our favourite note-taking apps for iOS and iPadOS. The Mac app interface is organised into four sections, including the main editing window. The Library is a Finder-style sidebar that shows note categories; to its right are the thumbnails of the notes in that category. There's a main edit panel, and a note navigator with thumbnails of the current note at the right. If you hide all the other panels, the editing panel automatically resizes and rescales. We found that quite annoying – hiding the panels made the text jump from 11pt to 20pt, and switching into full-screen mode took it to 48pt.

One of the things we like best about Notability on iOS is its support for Apple Pencil, enabling you to annotate, scribble, sketch, and highlight in a really natural way. You can do all these things with your Mac too, but unless you have a graphics tablet or use your iPad and Pencil via Sidecar it's quite awkward with a trackpad or mouse. And if you're going to use Sidecar you might as well use the iPad Notability app.

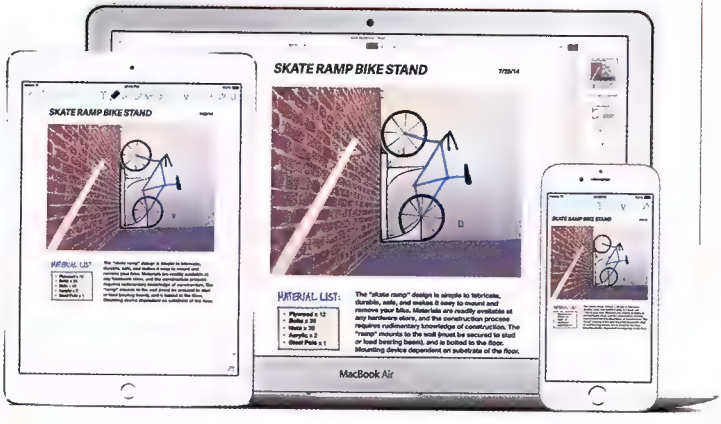
Note that handwriting recognition, to turn writing into editable text, and maths recognition, to turn equations into hi-res images, are in-app purchases (at $4.49 each).

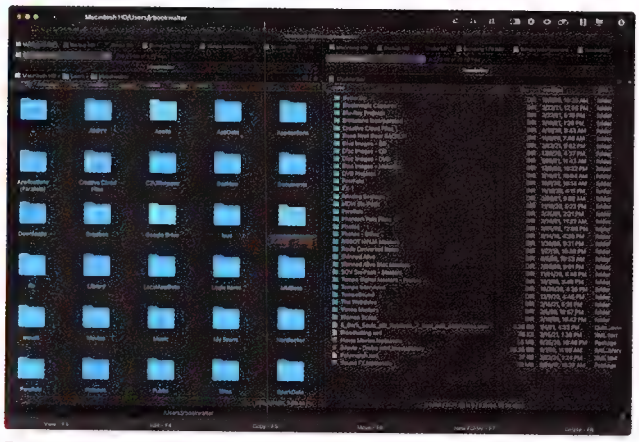
Notability on Mac is best considered as a companion to the iPad app.

■ This is a companion app rather than a standalone Mac app.

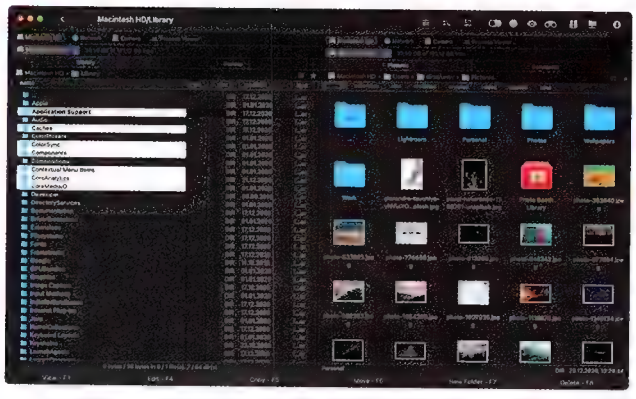
Carrie Marshall

★★★☆☆





The interface just doesn't feel like a native Mac app.



macOS 10.12 or later | Free (IAPs) | ftp-mac.com

Commander One 3.0

A dual-pane Finder alternative.

Despite Finder's advances, there are still Mac owners who feel it doesn't go far enough. Commander One 3.0 is a versatile dual-pane solution with support for unlimited tabs, hotkey shortcuts, built-in Command Line bar, and FTP client that speeds up everyday tasks, and eliminates the need for third-party utilities. It also now directly accesses cloud storage services Google Drive, OneDrive, Mega, and pCloud, as well as Dropbox and Box.

There's now full support for Big Sur. The app remains Intel, although it installed and ran fine on our M1 MacBook Pro. Despite the claims of faster data transfer rates, we found the Apple silicon-enhanced Finder copied an 80GB Parallels VM to a USB 3-connected external SSD in just under three minutes – about 10 seconds faster than using Commander Pro.

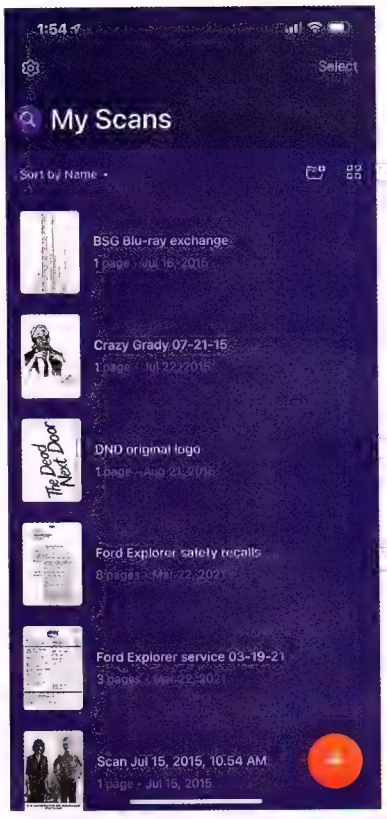
The overcrowded interface is chock full of options, but file manager competitors Path Finder or ForkLift feel more like native Mac apps while also improving discoverability of crucial features, which are largely buried here.

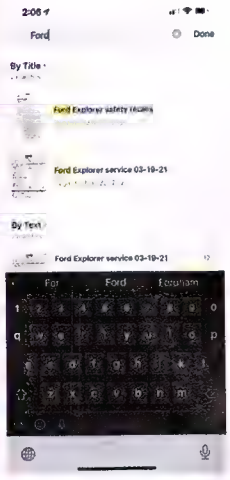
That said, compatibility with macFUSE 4 enhances Commander One's handling of native file systems, as well as those from third parties. Amazon S3 users will also like a new option to use path-style URLs when accessing their buckets.

■ A modest update for everyone but macOS Big Sur users.

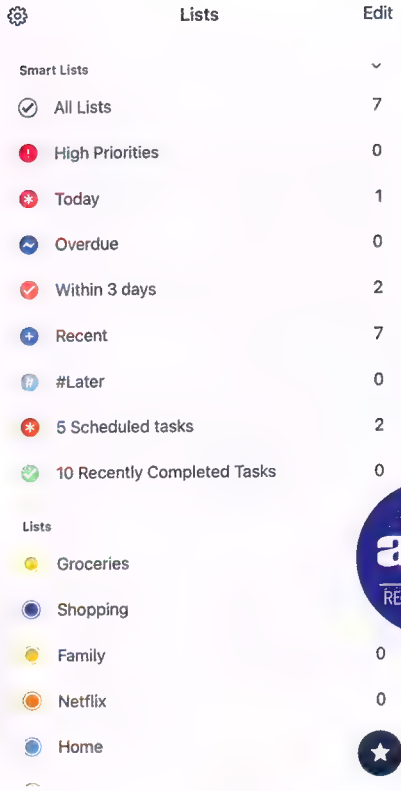
JR Bookwalter

★★★☆☆





Left: The refined interface ncludes the option to display docs in list view.
Below: Always find what you're looking for from the home screen search.



You can create Smart Lists based on task parameters.

iOS 11 or later | Free (IAPs) | readdle.com

Scanner Pro: PDF Scanner App

Excellent free mobile scanner.

Scanner Pro has recently been updated to version 8.0. The biggest change? The app is now free, so everyone benefits from auto crop, shadow removal, iCloud syncing, and sharing with others – albeit with a watermark. This limitation can be removed with a Plus subscription ($19.99/year), which also enables on-device OCR in 26 languages, full text search, password protection, and automatic upload workflows. These and other current features remain unlocked for those who own the paid version; developer Readdle plans to introduce additional goodies that may or may not require a subscription.

The update also enhances Scanner Pro's look and feel, and organisation approach. The interface now uses dual shades of eye-pleasing purple, with the option to view scans as thumbnails or in a list. New sorting options allow finding docs more quickly by name, date created, or date modified.

The Text Vision feature recognises scanned text in a document so you can copy or share it, and the app now uses that data to make the content of all saved files searchable. This feature works from the app home screen or can be limited to the currently open document.

Better than ever, and now free for all to use.
JR Bookwalter
★★★☆☆

iOS 12 or later | Free (IAPs) | hahaint.com

GoodTask 6.4

Track everything about yourself.

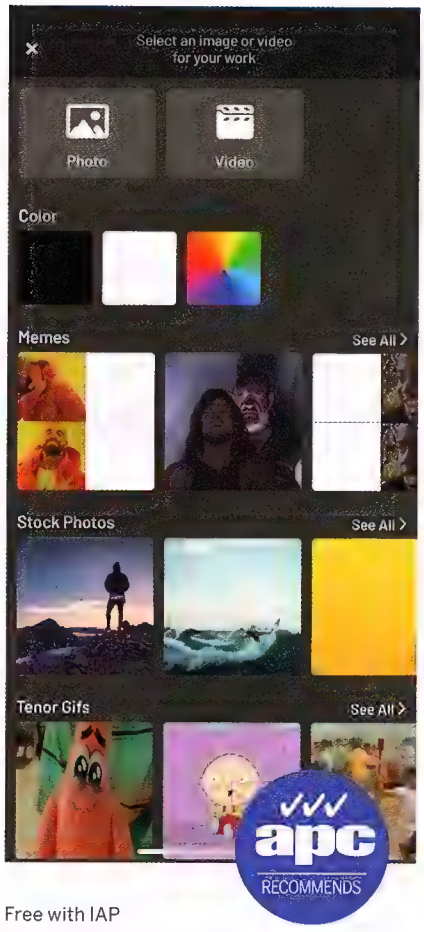
GoodTask makes the process of creating tasks as easy as possible. Version 6.4 adds a Board View that lets you easily view upcoming tasks by deadline in columns across the screen.

The app syncs with iOS Reminders and Calendars and pulls in lists from the former. You can pick which lists to include and create new ones, add tags to tasks and filter them to only see those with, or without, a specific tag. Actions enable you to create or edit parameters, such as title, due date, and notes. Quick Actions allow you to apply multiple Actions simultaneously. There are several ready to use, or you can create your own. You can also create templates – groups of tasks and subtasks – and apply one on any given day, or set it to recur.

The app can be customised with themes, and you can change font sizes and the way tasks are displayed. There's an accompanying Apple Watch app, and support for iOS Widgets. The Favorites widget lets you add a customised new task or directly open a list. And you can share lists using Share Sheets.

One of the few things GoodTask doesn't do is allow you to collaborate or delegate tasks easily with others. The iOS app costs $14.99 to unlock all features; the Mac version costs $62.99. That's still competitive and good value for money.

A powerful and highly customisable task manager.
Kenny Hemphill
★★★★☆



Free with IAP

Mematic

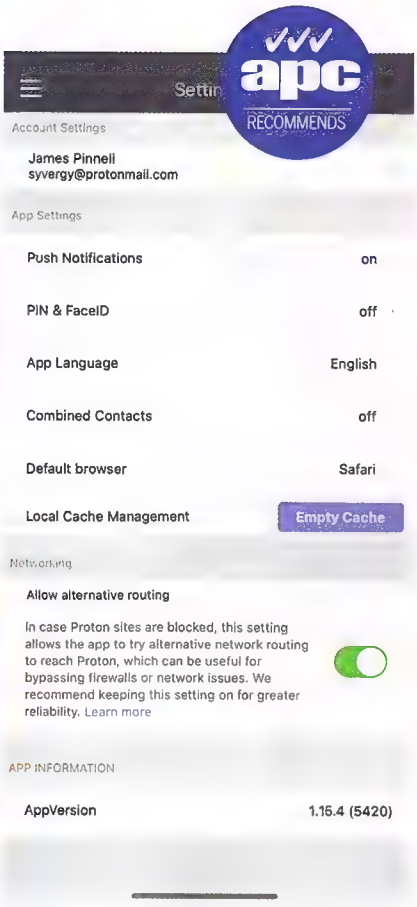
Galaxy Brain your memes.

Have you ever discovered a perfect opportunity for a meme – whether it's the middle of a rapidly flowing group chat or a snarky back and forth on twitter – but are stuck without the means of production? Never fear, because Mematic is here.

Mematic effectively takes the most popular meme templates on the web, everything from Drake dismissing to a girlfriend looking horrified, and allows you to fill the spaces with your own hot takes and humorous references.

There are dozens of raw templates, plus hooks into the latest gifs and Jpegs making the rounds for you to choose from. You can even upload your own pictures and the app will memeify them to an extent for you to edit. It's all very… 2021.

★★★★☆



Free with IAP

Proton Mail

Secure, free, email.

In 2021, email is about as ubiquitous as water. Everyone has it, checks it roughly 12 times a day and most of us allow a tech giant to host it for us. Unfortunately, those giants also tend to take sneaky peeks inside that email in order to sell us, well, everything.

Proton Mail aims to change that. It's a completely free, ad-free, email service that pledges to not only stay out of your email contents but also ensure that everything you send stays as secure as possible via encryption.

But it's not just mail – the free tier also includes calendar and contact management in the cloud. While the storage level isn't at the level of Google or Microsoft (only 500MB and 150 messages sent/received), you can upgrade for roughly $4 a month, or 30% more if you subscribe through Google or Apple's stores.

★★★★☆

Free with IAP

Wokamon

Walk to poke'.

Wokamon has a singular mission – to get you to walk. It doesn't matter how (treadmill, path, edge of a cliff) or how it's tracked (watch, Fitbit, pedometer, phone) but it needs you to wake up Wokamons, who have been laid dormant after laziness took over their friends, the Layabots. Wokamon is part idle clicker, part walking gamification. The more you walk, the more Wokamons you wake up and allow to evolve into bigger ones. It's a fun incentive to see gains from even the most basic movement – which is easier than many other similar apps that focus on running or more intensive activity.

Like Donut Dog before it, Wokamon provides not only a host of workout and health tracking information (in a fun and colourful layout) but it takes a difficult task to be motivated into completing and makes it more interesting.

★★★★☆

Linux | https://ubuntu.com

Ubuntu 21.04

Not a fan of release names, Mayank Sharma is even more perplexed by the one given to this release, since hippos aren't known to be hairy.

Ubuntu usually uses regular releases to introduce new developments that it hopes to stabilise by the time the next long-term release (LTS) rolls around. Yet despite the usual slew of updates, version 21.04 is rather light on show-stopping features.

For desktop users, the only noteworthy new feature is the switch to the Wayland display server by default, for supported hardware. Some other distros, such as Fedora, have been using Wayland for a while now, but Ubuntu has delayed making the switch. Now that it has, the developers note that some programs, including Firefox and OBS Studio, will use Wayland for smoother graphics and better fractional scaling.

Ubuntu tried using Wayland by default back with Ubuntu 17.10, before reverting to Xorg for subsequent releases. The X.Org session remains available for those that want to switch back to it or for unsupported configurations and other desktops

Ubuntu 21.04 is also missing the recently launched Gnome 40 desktop environment, which makes its way into the latest Fedora 34 release. Instead, Hirsute Hippo ships with Gnome 3.38 as it waits for the larger Gnome ecosystem to migrate to GTK4.

One behind-the-scenes highlight of the release is a fix for a long-standing security issue that was first reported in 2006. Unlike many other distros, Ubuntu by default creates user home directories with world writable permissions, which perhaps made sense in 2006 when having world-writable directories made Ubuntu more convenient for multi-user environments.

However, Ubuntu's security lead argues that these permissions could spell disaster in today's connected environment. He instead proposed changing the default settings to strip away write permissions from anyone except the owner of the directory.

While the release doesn't offer much to the average desktop user, there's a useful development for enterprise users, who can now connect to an Active Directory (AD) domain for managed configuration through a Group Policy client. Ubuntu developers note that with this feature system admins can set security, password and user access controls, and configure and manage settings like desktop background and default programs for the entire install base.

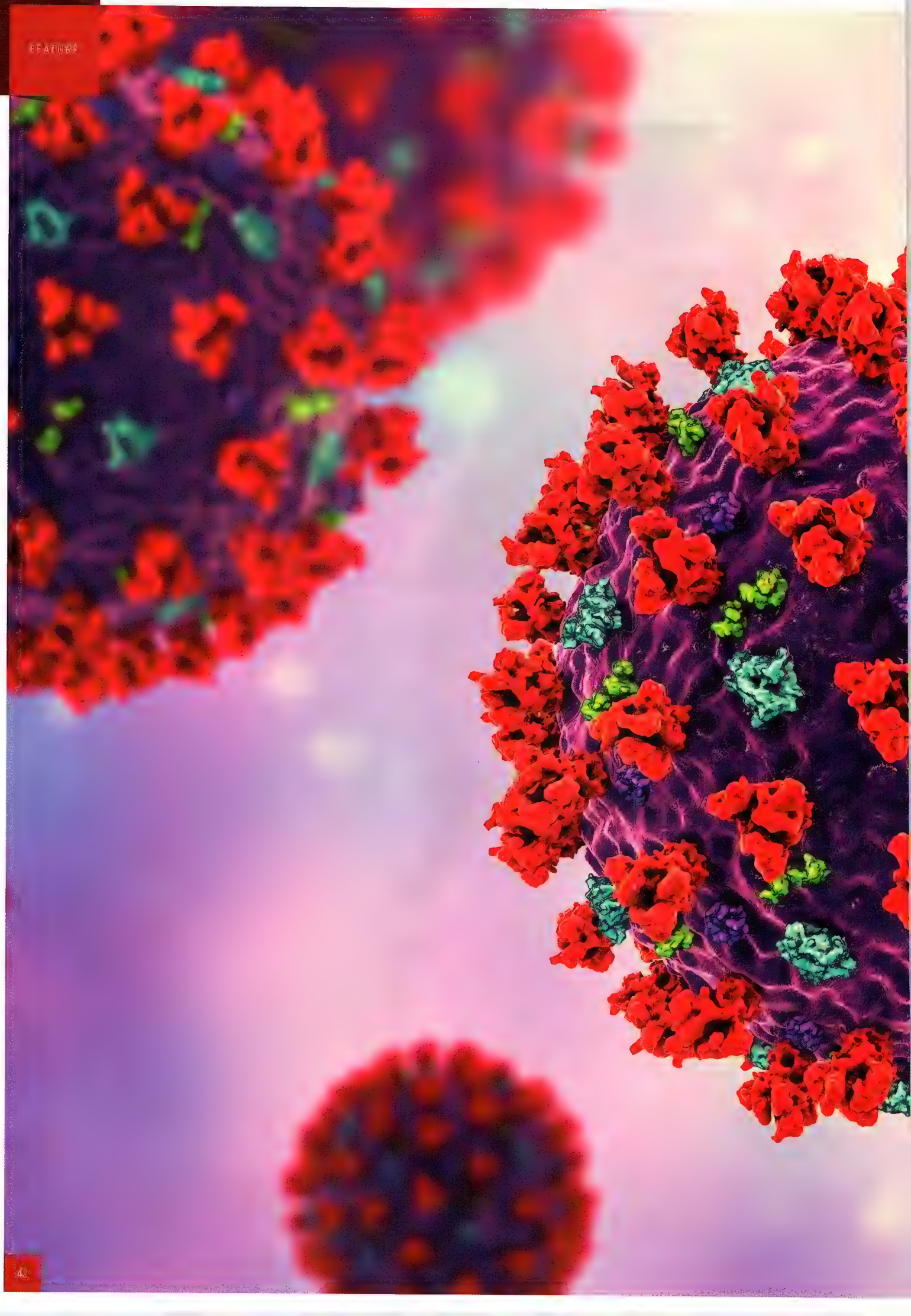
In a comprehensive benchmark conducted by Phoronix, which pitted the current release with a couple of previous ones, on an AMD EPYC 7763-powered machine, Ubuntu 21.04 came out on top in more than half of the 90-plus tests. Taking the geometric mean of all the benchmark tests puts Hirsute Hippo about six percent faster than Ubuntu 20.10.

Talking of the previous release, don't be surprised if you don't get a notification on your 20.10 installation prompting you to upgrade to the latest release. That's because, in a strange turn of events, a severe issue has forced Ubuntu developers to disable the upgrade prompt. While a manual upgrade is still possible, some top Ubuntu developers want the distro to actively discourage users from upgrading.

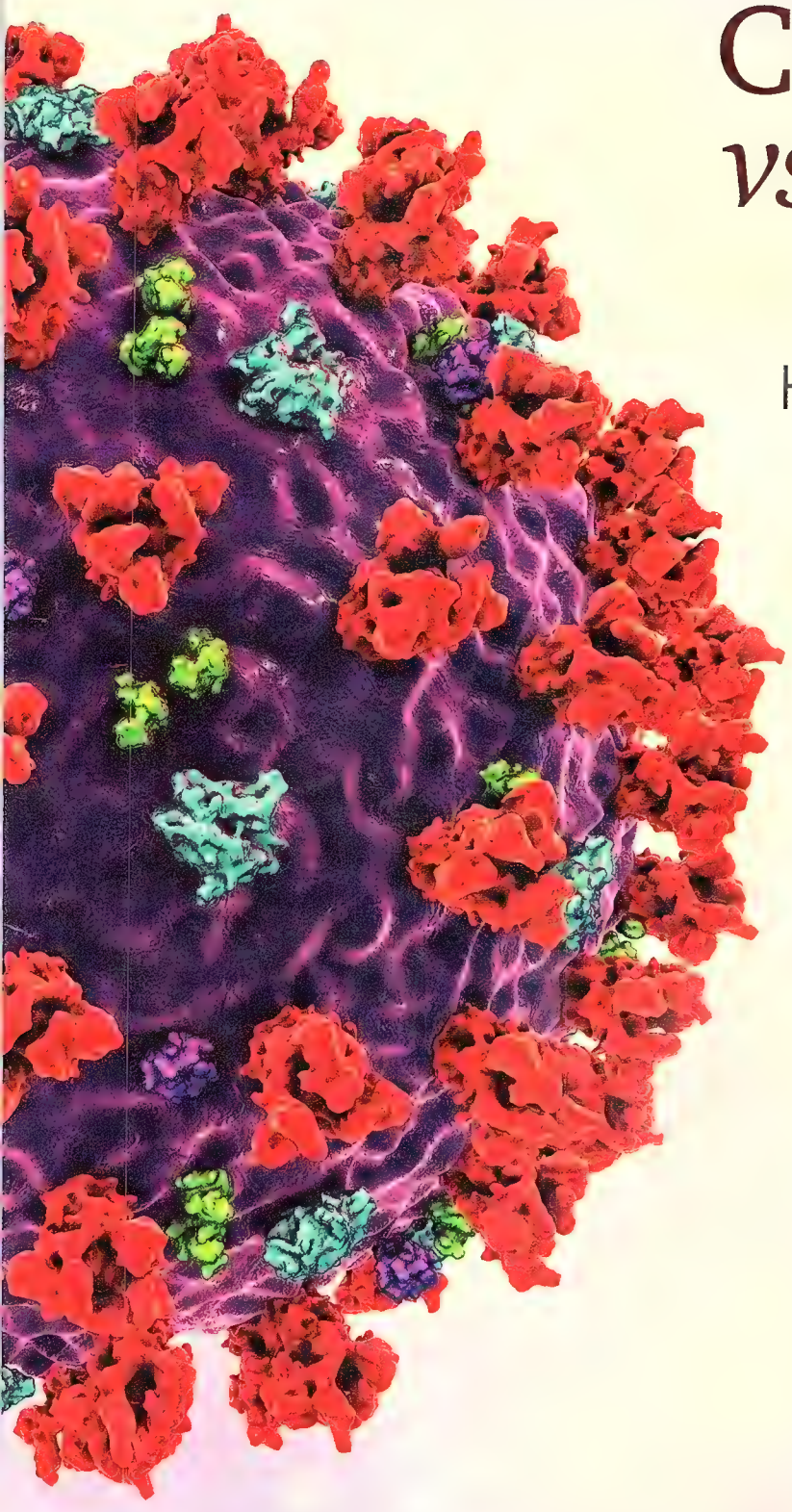
The issue stems from a bug in the shim that enables Ubuntu to boot on Extensible Firmware Interface (EFI) equipped machines. The shipped version of shim in Ubuntu 21.04 isn't compatible with EFI version 1.10 and will make these computers unbootable after the upgrade. Upgrade notifications will be enabled once a new version of shim is available that works.

A run-off-the-mill Ubuntu release that doesn't include many headline features. For now, best to hold off updating to it.

★★★½☆



FEATURE



Coronavirus *vs.* the giant computer

How Folding@home took time off from curing cancer to tackle a pandemic.

BY IAN EVENDEN

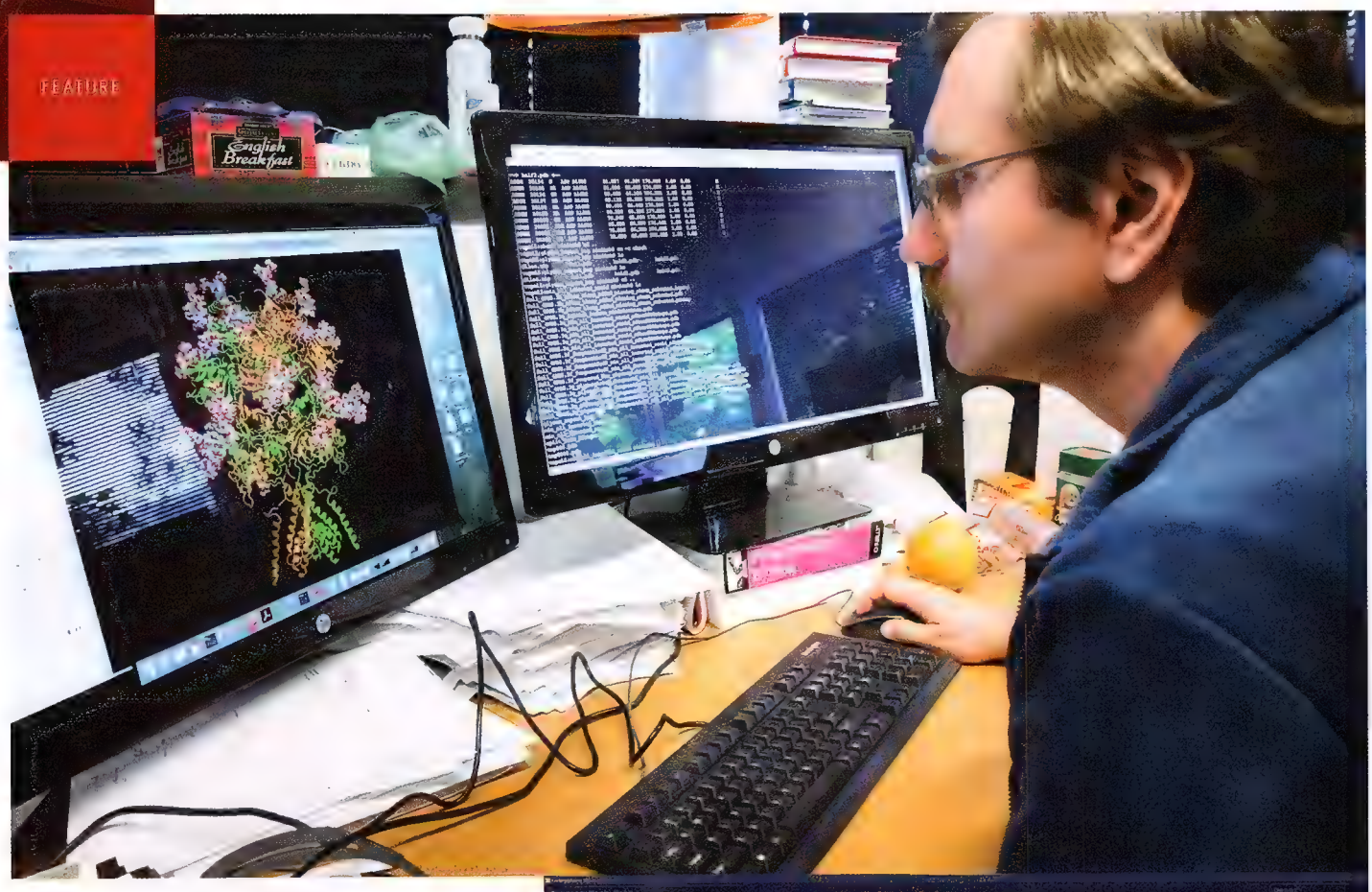
When the *APC Illustrated Bumper Book of World History* is written, the years 2020 and 2021 will get their own chapter. Not because of politics but because of the global pandemic and shortage of microchips.

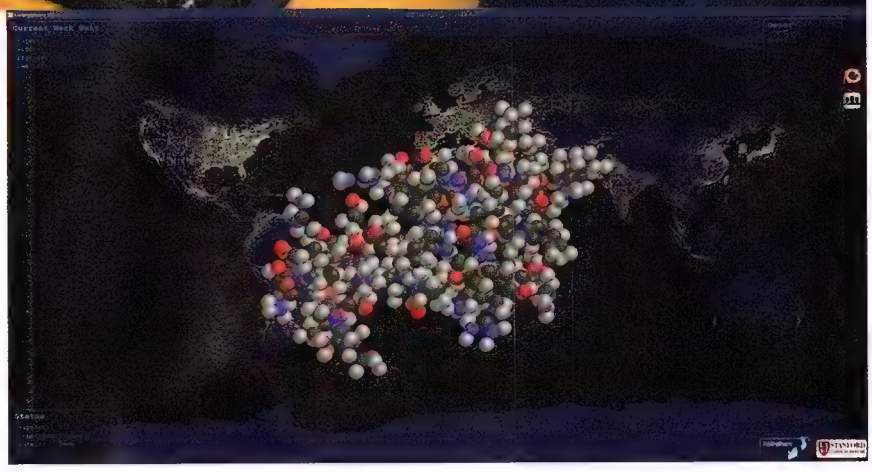
Folding@home will probably need a lot of coverage, too – a citizen science project contributing to biochemical research projects that is free to add to and feels extremely cool while you do it (except for the heat it pumps out of your PC case).

There's not much we can do about the chip shortage, but the pandemic and Folding@home collided beautifully. It led to Folding@home becoming the fastest supercomputer on the planet, hitting one exaflop (a 1 followed by 18 zeros) on March 25, 2020, then peaking at 2.4 exaflops the next month. That's as powerful as the top 500 (known) supercomputers combined. And that much power folds a lot of proteins.

But why would we want to fold proteins in the first place? Look up any image of one online, and it seems pretty well folded already – all spirals and ribbons, like your little sister's hair on her birthday. The record was there for the taking, however, so here's how Folding did it.

© Getty Images/Kateryna Kon/Science Photo Library





Top: Anton Sinitsky of the Pande Lab, Stanford, works on Folding data. **Above:** Folding's visualiser, which comes with the client, gives an idea of both the complexity of the molecule being simulated, and the location of Folding participants.

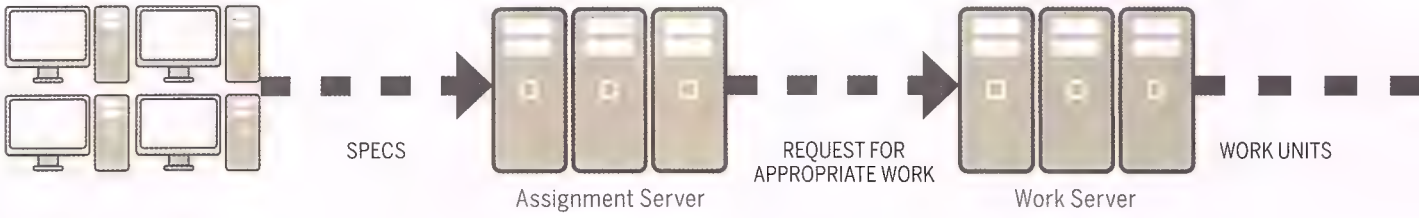
Folding@home is used to breaking records. "Back in 2010, 2012, we had a client on the PlayStation 3," says Anton Thynell, head of collaboration and communication at Folding. "That's where we took our first Guinness world record for the world's strongest distributed computing network, with I think 800,000 PS3s and a couple of hundred thousand PCs. Folding@home has a very strong community, and it's well known in tech. I think what resonated most, though, is that you can donate your computing power to research. We're not asking for funding, we're asking for computing power, and that power is directly connected with the simulations researchers are running."

Since its launch back in 2000, over 200 scientific papers have been produced as a direct result of Folding@home processing, including one in June this year, published in Nature Chemistry, that announced the discovery of "cryptic pockets" on the surface of the virus that offer targeting options for new antiviral drugs, as well as epitopes – protein fragments that are capable of stimulating an immune response. This is a clear-cut breakthrough, and we dread to think how long it would have taken had Folding not been able to scale up so effectively. The data and models are being made freely publicly available.

Protein folding is a complicated thing to simulate – the exascale computer Folding created for its COVID paper managed to simulate just 0.1 second in the life of the virus's proteome (all the proteins that are, or can be, expressed by a genome) – yet the benefits from doing so are huge. Protein misfolding is a causal factor in a number of diseases, including some cancers, allergies, Alzheimer's disease, cystic fibrosis, sickle-cell anemia, Creutzfeldt-Jakob disease, and type 2 diabetes. Then there's the way viruses, including HIV, influenza, and coronavirus,

© Folding@home

FOLDING@HOME'S JOURNEY



enter our cells – they have a protein on their surface that folds to be like a key, and this attaches to a lock on the surface of the cell, opening it up for infection if the key is just the right shape.

You may have heard of the "spike" protein on the surface of the coronavirus virion, and this is the key that opens our human cells to its contagion. Once open, the virus inserts its own genetic material – DNA and RNA – and tricks the cell into following these plans instead of its own, producing more virions. Other diseases, such as Alzheimer's, see fragments of misfolded proteins, known as prions, build up in the brain as plaques, which interrupt normal brain function. A curious property of prions is that they can transmit their misfolded shape to other, normal proteins, causing them to misfold and clump together.

This is unfortunate, because proteins are essential for the normal operation of our bodies. These complex molecules have a 3D structure, and it's this that allows them to do their work, in the same way the proteins on the virus allow it to open your cells like a key. If they fail to fold properly, they often become inactive, but sometimes they acquire modified or toxic functionality (interestingly, we frequently unfold proteins into their original linear state; a process known as denaturation. It involves heat, and we call it cooking).

The spike protein remains a tempting target, even though it has defenses, such as glycan molecules that act as shields. It also opens and closes, protecting the sites that bind with human cells – and therefore could be targeted by drugs – to evade the immune system. Folding has simulated the opening of the spike, showing how it binds to human ACE2 enzymes, which are located in cell membranes and play a role in reducing blood pressure, using them as an entry point into our cells.

What is a protein?

"A lot of attention gets paid to one other large molecule that's essential for life, and that's DNA," says Katie Hart, assistant professor of chemistry at Williams College, Massachusetts. "DNA is like the software, but the proteins, the enzymes, they do the chemistry. They are the structural bits that comprise your hair and various parts of yourself. Proteins are linear chains, so you can think of them as beads on a string, where each bead is an amino acid. They're linked in a particular order depending on what the protein does, so before it can do anything, the chain has to fold into a complex 3D structure."

The order the beads appear on the string is crucial for how the protein will fold. "The rules for what that structure looks like are actually all encoded within that sequence of amino acids," Hart continues. "You will always end up with sort of the same structure, simply because you have different flavours of amino acids. They have different chemical and physical properties, so some of them might be positively charged, others negatively charged, and the positive ones want to be nearer negative ones, and away from other positive ones. Some of them may be greasy or oil-like, while some are water-like and those want to be also kind of clustered together, so the oil-like amino acids want to cluster together and the water-like ones want to cluster on the outside. So, using a few simple rules you can predict what the final three-dimensional structure might look like."

The cleverest part of it all is that proteins do this spontaneously. Hart calls it "beautiful," and she's right. Chain together the right sequence of amino acids, then put them in water, and they will fold up and become a molecule of your hair, or fingernails, or muscle. Every. Single. Time. But this raises an obvious question: If we know how a protein will fold by looking at its parts, why do we bother simulating them in the world's largest supercomputer?

Well, it turns out that if you have many, many amino acids in the chain, it's actually quite difficult to predict precisely what they're going to do. "Once you have the problem of hundreds or thousands of these amino acids, and all of the shapes they could form, and all the ones that they're not going to form, it gets a little bit difficult," says Hart, who we suspect is understating the matter slightly. "On the one hand, it's an interesting question from the perspective of understanding the physics and the chemistry of the process. From a biological or human health perspective, all of your proteins have to fold to function, so if they're not folding properly, then that can be a problem."

X-ray vs. Computer

Before computer simulations, protein structure was determined using X-ray crystallography, in which X-rays were fired at a crystallised protein (to stop it moving about) and the diffraction patterns produced translated into the coordinates

ALPHAFOLD PREDICTS THE FUTURE

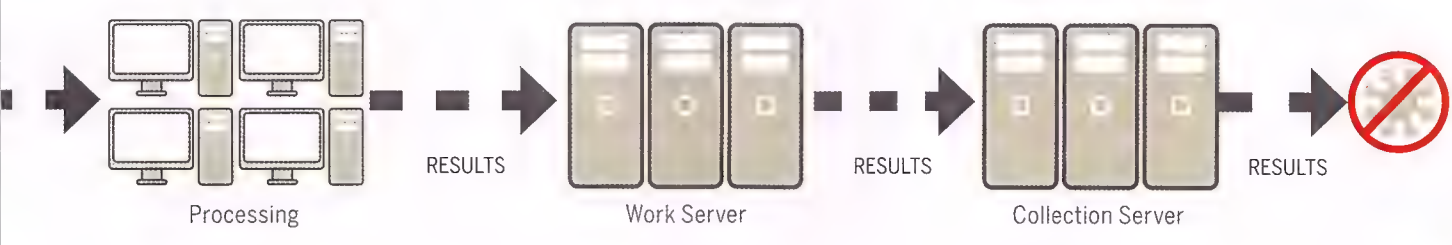
Folding@home isn't the only group that's interested in folding proteins. Google, via its faintly terrifying offshoot DeepMind (which has an AI that can play *Starcraft* much better than you can), has also been having a go, but its AlphaFold software takes a rather different approach.

Essentially, what AlphaFold has been able to do is sidestep the whole inconvenient simulation process, and go straight from looking at the flat chain of amino acids to its final 3D shape by predicting how it will fold, then honing that prediction to a remarkable degree of accuracy.

"It's a game changer," Andrei Lupas, an evolutionary biologist at the Max Planck Institute for Developmental Biology in Tübingen, Germany, told Nature. "This will change medicine. It will change research. It will change bioengineering. It will change everything."

AlphaFold has been at this a while. Every two years, a challenge called CASP (Critical Assessment of Structure Prediction) is held, in which scientists vie to most accurately predict the final 3D form from a linear chain. AlphaFold won in 2018, and was way ahead in the 2020 contest, with two thirds of its predictions equivalent to the results achieved by X-ray data.

While not yet perfect – it can take days to come up with a prediction – DeepMind's deep learning approach looks significant and could lead to whole new disciplines, such as protein design and the study of how they have evolved. "This is going to empower a new generation of molecular biologists to ask more advanced questions," Lupas continued. "It's going to require more thinking and less pipetting."



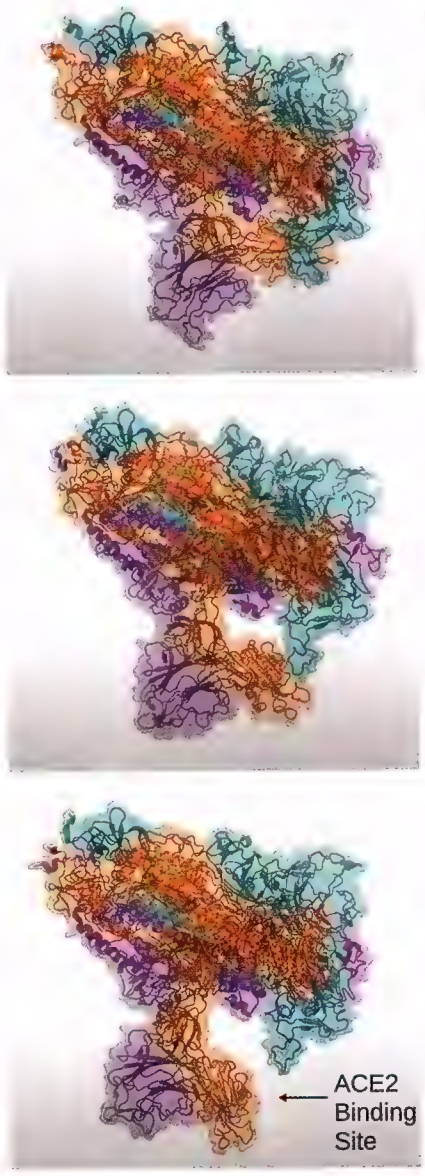
of its atoms, which could be built into a 3D structure using the ball-and-stick models that are as much a part of the ideal science lab as a skeleton in a white coat.

As we've seen, there are a lot of diseases that are caused, at least in part, by problems with proteins. We can add to that list aging disorders, where the same sort of plaques that in the brain might cause Alzheimer's build up in other organs of the body. "Being able to prevent misfolding or promote proper folding using drugs or therapies is one of the main kinds of biomedical relevance of understanding protein folding," says Hart. "Protein folding is not just about achieving the final, folded structure. Proteins are highly dynamic, meaning they move around and wiggle a lot. So, we need to understand not just how a particular string of amino acids folds into one structure, but also how it moves and rearranges in solution to form a whole family of similar-looking structures. Then we can better design drugs that target these structures – just as Folding@home has been doing most recently to discover drugs that target proteins in COVID-19."

Ah, yes, that pesky pandemic. Millions of new donors – computing time donors – flocked to Folding when it announced it could apply its technology to finding a cure, or at least a treatment, for the disease ravaging the globe. At the beginning of 2020, there were around 30,000 devices donating their spare computing time to the project. At the time, one of the big areas of research was in myosin motors, molecules that move along the cytoplasm of animal cells, turning ATP, the universal chemical energy currency of the body, into mechanical movement along microfilaments within the cytoskeleton, the protein structure that exists inside every one of our cells.

Make tiny changes to these myosin motors, and you change their function. This was interesting work that opened up new ways to fight Ebola, and showed how an existing antiviral drug, Baloxavir, could be repurposed to fight thrombocytopenia syndrome virus, which is spread by ticks in the US, and has a mortality rate of up to 30 percent.

"All the labs that are connected with Folding have their own focus," says Thynell. "We're talking about biomedical research, disease research, it depends on the different labs. If you take Washington University in Saint Louis, for example, they focused on the Ebola virus and through Folding@home they've uncovered some potential druggable sites. Ebola has been called undruggable, but through their simulations we could discover previously hidden sites [for drugs to interact]." And that was going extremely well, until the scale of the COVID-19 pandemic revealed itself and Folding pivoted all its attention on to the new



These frames from a Folding@home video demonstrate the spike protein on the SARS-Cov-2 virus opening, and show where it binds to the human ACE2 site.

threat. Within two weeks, 400,000 new devices had signed up, pouring the resources of 4.8 million CPU cores and 280,000 GPUs into discovering the secrets of SARS-Cov-2. An internal joke at the project was that this effort generated more simulation data than had been created in the entire history of science to that point. It looks like it might be true.

Another problem with COVID is that, for something just 200nm across, it's quite sneaky. Take the Nsp16 protein – this helps the virus avoid the human immune system because it's very similar to CMTr1, a normal human protein. Design a drug to target Nsp16, and you have to be careful you don't take CMTr1 down, too. Folding has discovered (see *Biophysical Journal*, March 2021) that there are druggable sites on Nsp16 that don't appear on CMTr1, paving the way for an antiviral drug.

Worldwide effort

Look at the map of where Folding's donors are in the world, and the US and Europe glow brightly, but so does Japan, parts of South America, the west coast of Australia, and both islands of New Zealand. There are outcrops of donors in Russia, India, South Africa, Hawaii, most of Southeast Asia, and what we think are the islands of Reunion and Mauritius, though geography was never our strong point. The Caribbean is ringed by dots representing donors, and a single dot glows way north in the Canadian Arctic. There's a very real sense of the world coming together to fight back, almost like at the end of a harrowing sci-fi movie.

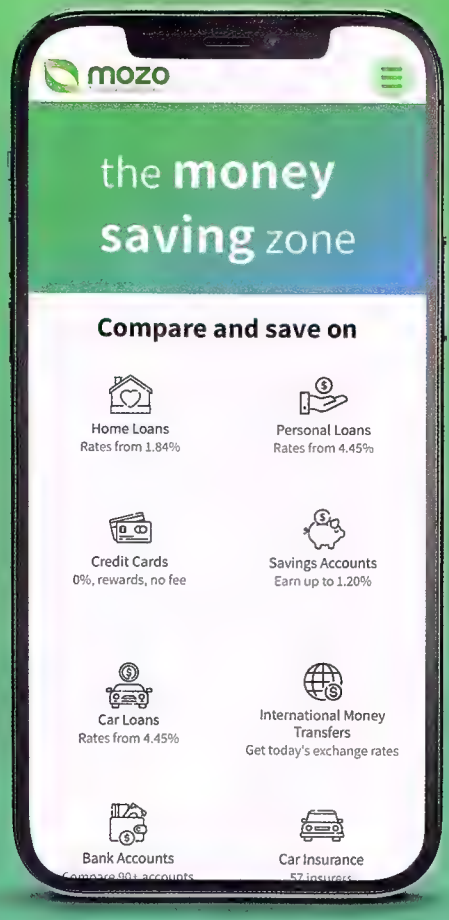
Speaking of movies, a lot of fantasy and sci-fi references are used to describe the project. Not only is the spike protein on the surface of the coronavirus referred to as the "demogorgon" (to be fair, the spike protein opening really does look like the creature from *Stranger Things*' mouth), but lead researcher Greg Bowman, writing on the Folding blog, describes the effort to target the coronavirus as being like "the citizens' fleet in the movie *Star Wars: The Rise of Skywalker*. Everyone came together to face a common foe."

Thynell uses a *Star Wars* reference, too. "We look at Folding@home as being a bit like the Millennium Falcon," he says. And before we can speculate about what he's smuggling, continues: "The Millennium Falcon isn't the perfect ship, but it's doing its job very well, and it's the fastest ship in the galaxy as far as we know, right? That's Folding@home for you. We were one part-time engineer and tons of great community."

So, should we visualise Folding as running on a few old Macs in the corner of a lab, or as a sleek stack of server blades in an air-conditioned data center? The truth is somewhere in between.

"The Folding@home Consortium has at least one work server," says Thynell. "The client first connects to the assignment server, from where we can measure how strong your computer is in terms of CPU and GPU. Then you connect to the work server to get a project that's fitting for your rig. The researchers upload their simulations to the work server, which are then distributed into the grid. When you've finished a project, you return it to the work server, and when the entire project is completed, it's moved over to a collection server, which is more like cold storage; its speed is less important. The work server requires SSD drives, while the collection server uses mechanical hard drives."

These servers are dedicated to Folding, but remain part of Washington University in St. Louis, and could be used for other things if not needed. Servers have been donated from the data industry, too, as has lots of computing power. Look at the list of top donors and you'll see the Nvidia Saturn V, a GPU-powered supercomputer built for



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The money saving zone

Dr. Greg Bowman (pictured center, brown shirt, along with the rest of the Folding team) is Folding@home's chief researcher.

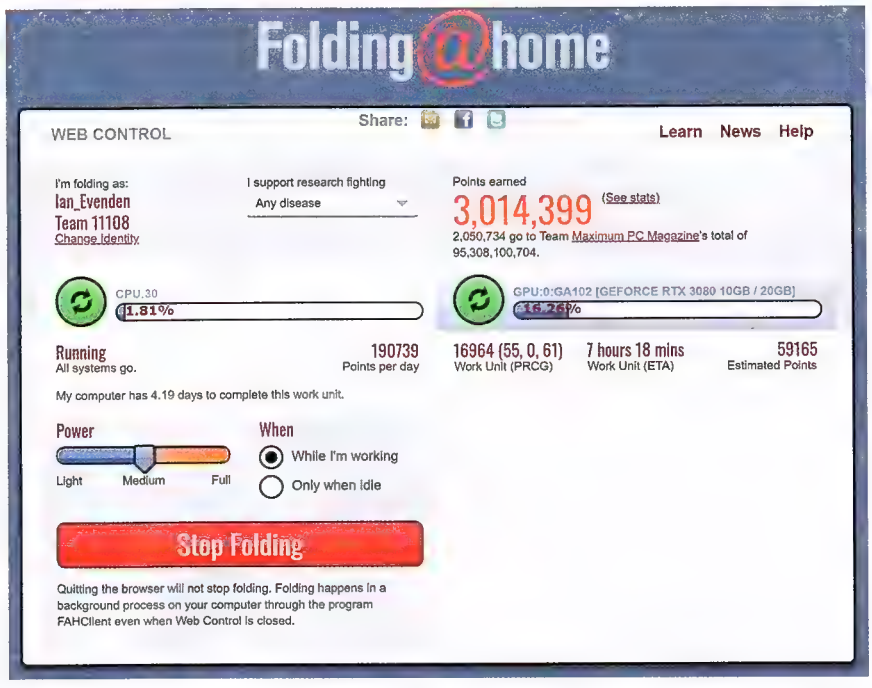
AI applications that seems to spend its spare time folding proteins.

All these GPUs in one place puts a question into our heads: Could someone infiltrate Folding and get it to mine bitcoin? We're not the first, it seems. "People have been asking that," Thynell says. "And it's not possible at all. Folding@home is based on two cores, and both of them are open-source research tools. What you download is these two cores, and then a wrapper and a front end, so you couldn't run any crypto-mining even if you wanted to with that client. You'd need to create a new client with different logic."

Moonshot drugs

Back to the more serious business: All that computing power is beginning to bear fruit against COVID. "Folding@home has been part of a larger effort called the Covid Moonshot, and they are at the end of animal testing right now with an oral inhibitor for SARS-Cov-2. The working thesis is to create a pill you'd take when you have symptoms – trials are successful so far, but it's hard to say how it will materialise. This would help countries that won't be running a vaccination program in the near term, as there's still a lot of vaccines left to be distributed."

This is obviously huge news. The Moonshot project is especially interesting because, as well as being open source and patent-free, it represents the coming-together of diverse groups such as the Diamond Light Source (the UK's national synchrotron science facility, like CERN only smaller), the Chodera Lab at the Zuckerman Research Center in Manhattan, the Weizmann Institute of Science in Israel, and private companies giving their resources for the good of humanity from China, India, Europe, and the US. A rather honest Q&A on the site



Folding@home's web interface is where you can see what it's processing right now, and even choose the disease you're interested in fighting.

admits they don't know how they're going to profit from the research, although the cynic in us suspects they'll find a way. Funding is currently handled through GoFundMe, with all money raised spent on the synthesis and testing of compounds, while any that remains unspent will be donated to fund not-for-profit research into the prevention of pandemics.

The Moonshot works by testing molecules against simulations of the COVID virus to see what effect they have. Those molecules aren't random; they're designed by chemists as a "best guess" at what might interact based on research like the discovery of the Nsp16 protein's vulnerability, and Folding's new Nature paper is likely to stimulate more. Over 14,000 such molecules were submitted, and in six months, over 1,000 were tested. One – the inhibitor – kills the virus in human cells without damaging those cells, but there are three other promising compounds on their way to testing.

"It's been really nice to be able to contribute to that, even though Folding@home concentrates on simulations," says Thynell. "Our understanding of SARS-Cov-2 will be very good now, thanks to all

we learned from the simulations, and our basic knowledge will be fruitful for future pandemics. If this virus comes back in another form, we have more information than we had previously." This is true, too, for the work involving the Nsp16 protein we referred to earlier. The protein is the same in the coronaviruses that cause COVID-19, SARS, and MERS, so a drug that targets one could potentially be used against all of them, and future variants.

ARM unleashed

As a result of the sheer amount of data the project is generating (Amazon Web Services provides infinite buckets for it to keep its datasets in), the team behind it is expanding, and a non-profit organisation is being set up to handle the grants and funding. "We really want to provide a great experience, but we don't have a triple-A budget for it, so we're doing the best with what we have. We're onboarding more engineers, and we're going to improve the client," says Thynell, before revealing the software will soon be available on more devices, including low-powered ARM machines. "So, you could have your Raspberry Pi running Folding@home, if you want."

That's going to mean further specialization of the projects the server sends out, retaining the heaviest work for those with gaming GPUs to spare, reserving those that would respond to multiple CPU threads for multicore monsters, and having a supply of lightweight, shorter projects for ARM devices. "We have projects where it doesn't make sense to run one very long calculation," says Thynell. "But instead a lot of very short calculations, and it's better to run those on an ARM device than on a GPU. It's the same back end for ARM devices, we just flag them differently in the system to make sure they get the right projects and not something designed for an RTX card." Exploring Folding@home's statistics page can be fascinating, seeing how the work breaks down by OS, which projects are popular (cancer was the most-gunned-for condition when we last looked, with COVID in second place), and being able to see the faces of the researchers, and read what they hope to do.

Katie Hart is assistant professor of chemistry at Williams University.

In this sense, and much like the viruses it simulates, Folding@home is constantly evolving. "We've been around for 20 years, and we're still going to be here in 20 years' time," says Thynell, before getting Trekky again. "We're the *Star Trek* Enterprise in the field of biomedical research. We are on the front line, and what Folding@home is doing today will be industry standard in 10 years' time, so we are moving the field forward, too. We're really making a difference in mapping out and learning more about the blueprint of the human body, and also getting people engaged. One thing we're focusing on in the future is educational content, and trying to improve our user experience. Understanding what's happening, and getting feedback from the client about what it's doing, could be better.

"The new generation is used to *Fortnite*, so it has to be as simple as *Fortnite* [to get Folding running]. We have an open-source developer community, and we're doing more and more in collaboration with our communities. We're on Discord and GitHub if anyone wants to get in touch."

Folding@home represents something wonderful – the world coming together to fight a threat, putting aside things like borders and business interests and our built-in distrust of one another. If it can create an exascale supercomputer to fight one virus, think what could be achieved if we attacked other problems in this collective, community-minded way. In 20 years' time, when our PCs will be so much more powerful, we may think of COVID and Ebola in the same way we think of smallpox today, a relic, consigned to that big book of world history by technology. ■

GET STARTED WITH FOLDING

If your PC is connected to the Internet, there's nothing stopping you from beginning to fold immediately. Point your browser at **https://foldingathome.org/#downloads** and choose your operating system. From there, install the client, and set up an account. Perhaps join a team, which pools the research carried out by multiple donors and turns it into a kind of competition between teams as to who can process the most work units.

The minimum specs are very low, in the Pentium 4 and Windows XP range, but the more cores you can give it, the happier it will be, and only a limited number of projects are available for 32-bit systems. Once connected, you'll find the client lurking in your system tray. There are two control panels: Web Control, which runs in the browser, and gives you a basic overview of what Folding is doing with your system; and Advanced, which is its own app, and gives you more detail and more control. You can pause the process, set how much of your system's resources you want it to use, and whether you want it to use both your CPU and GPU (multiple GPU owners can add a second GPU slot, and potentially process three work units in parallel). You can also set it to only work when your PC is idle, leaving all the power for you when you want to work.

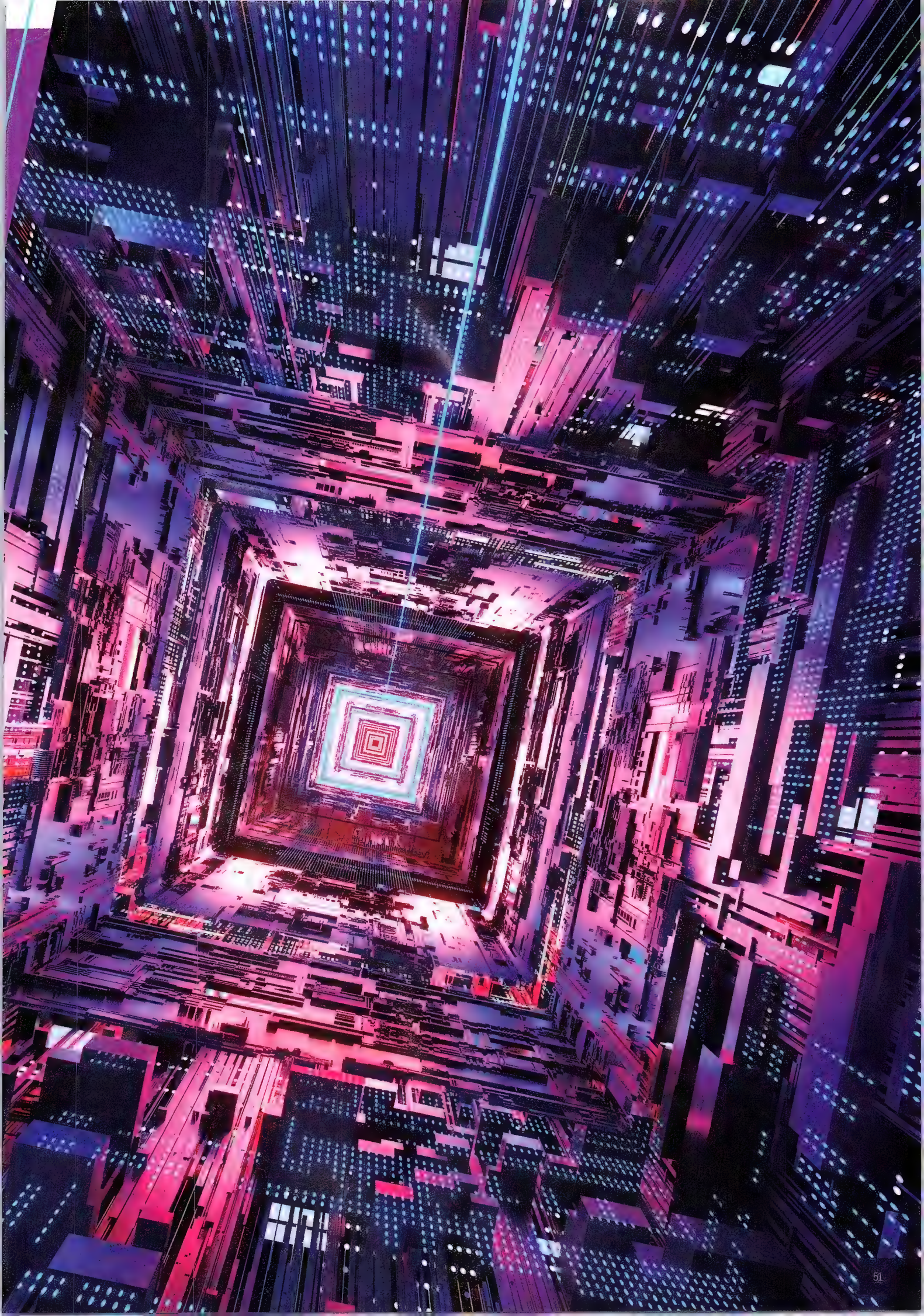
We had to turn the "Power" setting down to "Medium" on our AMD Threadripper/Nvidia RTX machine, simply because the heat it was generating from running full-tilt was making it uncomfortable to work in our office. Watch out also for clashes between Folding and your antivirus software – if this happens, exclude the "Folding" folder from your antivirus scanning list.

THE MACHINE LEARNING REVOLUTION

According to the hype, artificial intelligence will soon be capable of anything. Jeremy Laird examines the true nature of machine learning.

It's the next big wave of computing. So says Intel, of artificial intelligence (AI). If anything, that's underselling it. According to some evangelists, AI is the key to unlocking almost every major problem humanity faces, from a cure for cancer to limitless clean energy. Less optimistic observers, including philosopher and neuroscientist Sam Harris, see AI as one of the most pressing existential threats to the survival of mankind. Either way, as Dr. Emmett Brown would put it, it's pretty heavy. Even a brief analysis of the implications of AI quickly takes on epic proportions. Back at the more practical end of the epistemological scale, getting a grasp on current commercial implementations of AI can be equally baffling. Machine learning, deep learning, neural networks, Tensor cores – keeping track of the processes and hardware, not to mention the jargon, associated with AI is a full-time job.

So, the long-term impact of AI may be anyone's guess. But, in the here and now, there are plenty of questions that can at least begin to be addressed. What is AI in practical computing terms? What is it used for today? What kind of hardware is involved and how are AI workflows processed? And does it add up to anything that you as a computing enthusiast should care about? Or is it just a tool for Big Tech to bolster their balance sheets?



Nvidia's new RTX 30-series graphics cards sport third-generation Tensor cores for accelerating AI workloads.

Buzzwords and bullcrap or the greatest paradigm shift in the history of computing? What, exactly, is artificial intelligence, or AI? According to the hype, AI won't just radically revolutionise computing. Eventually it will alter almost every aspect of human life. Right now, however, defining AI and determining how relevant it really is in day-to-day computing, that's not so easy.

Put another way, we can all agree that when, for instance, the self-driving car is cracked, it'll have a huge impact on the way we live. But more immediately, when a chip maker bigs up the "AI" abilities of its new CPU or GPU, does that actually mean much beyond the marketing? Whether it's a graphics card or a smartphone chip, is the addition of "AI" fundamentally different from the usual generational improvements in computing performance?

Taken in its broadest sense, AI is any form of intelligence exhibited by machines. The meaning of "intelligence" obviously poses philosophical problems, but that aside, it's a pretty straightforward concept. Drill down into the specifics, however, and it all gets a lot more complicated. How do you determine that any given computational process or algorithm qualifies as artificial intelligence?

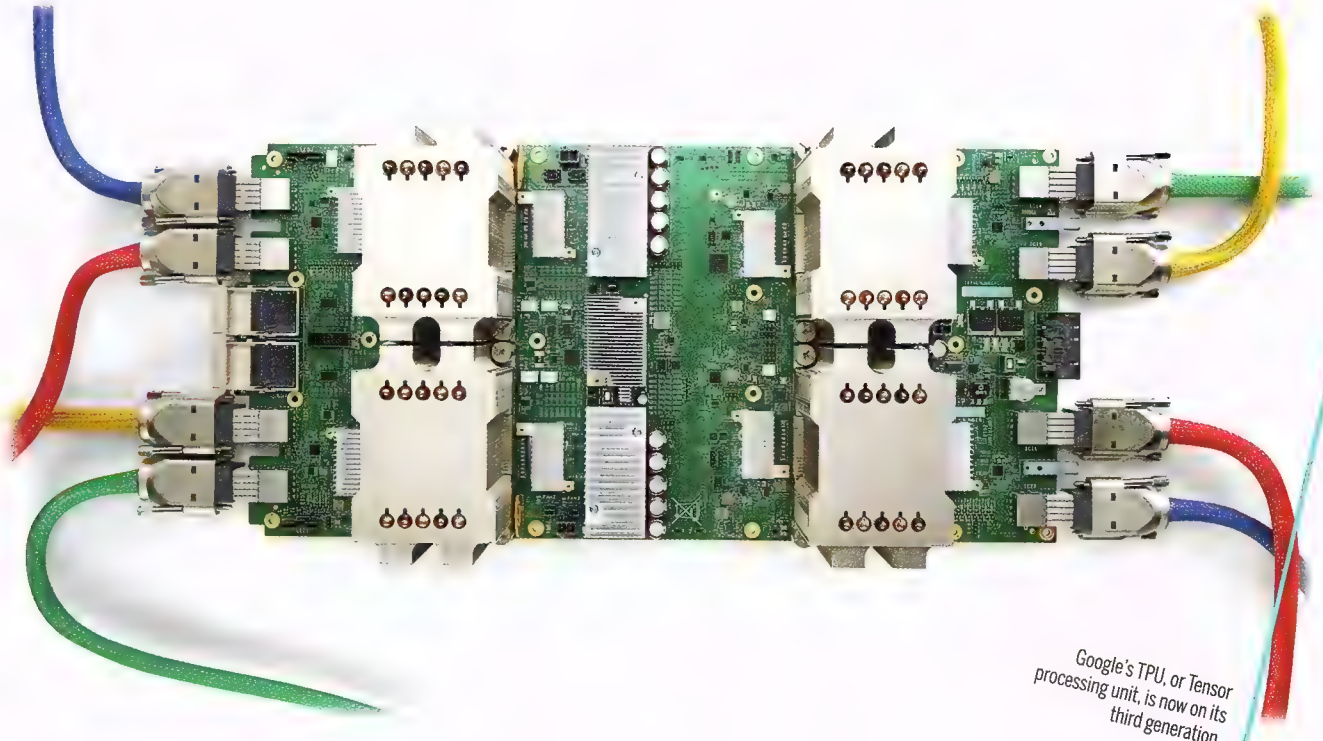
What defines AI?

One way to define AI is the ability to adapt and improvise. If a given process or algorithm can't do that to some degree, it's not AI. Another common theme is the combination of large amounts of data with the absence of explicit programming. In simple terms, AI entails a system with an assigned task or a desired output, and a large set of data to sort through, but the precise parameters under which the data is processed aren't defined. Instead, the algorithms are designed to spot patterns and statistical relationships, and learn in a trial and error fashion. This is what is otherwise known as machine learning and it's usually what is meant when the term AI is used in a commercial computing context.

A good example of how this works in practice is natural language processing. A non-AI approach would involve meticulously coding the specific rules, syntax, grammar, and vocabulary of a given language. With machine learning, the algorithmic rules are much less specific and all about pattern spotting, while the system is fed huge amounts of sample data from which patterns eventually emerge.

GPT-3

Generative Pre-trained Transformer 3 (GPT-3), developed by San Francisco-based OpenAI and released in 2020, is just such a machine learning natural language system. It was trained using billions of English language articles harvested from the web. GPT-3 arrived to much acclaim, with The New York Times declaring it "terrifyingly good" at writing and reading. In fact, GPT-3 was so impressive, Microsoft opted to acquire an exclusive license in order to use the technology to develop and deliver advanced AI-powered natural language solutions, the first of which is a tool that converts text into Microsoft Power Fx code, a programming language used for database queries and derived from Microsoft Excel formulas.



Google's TPU, or Tensor processing unit, is now on its third generation.

AI-powered autonomous driving features, such as Tesla's Autopilot, have proved more difficult to develop than expected.

A CHIP-DESIGN GURU AND THE UNFATHOMABLE FUTURE OF AI

CPU architect and tech legend Jim Keller on machine learning.

Is there anybody involved in chip design with a better résumé than Jim Keller? He's the brains behind not only AMD's first CPU architecture to really sock it to Intel (that'll be Hammer back in the 2000s), but also the driving force that led to Zen and AMD's renaissance in the late 2010s. He sired Tesla's Autopilot chip, set Apple on the path to building arguably the most efficient client CPUs available today, and more recently had a stint at Intel.

Now Keller is heading a start-up, Tenstorrent, specialising in custom chips for accelerating AI workloads. That fact alone is enough to lend serious credibility to the field of AI and machine learning. According to Keller, there are now three kinds of computers. First there were CPUs. Then came GPUs. Now, the AI computer has arrived.

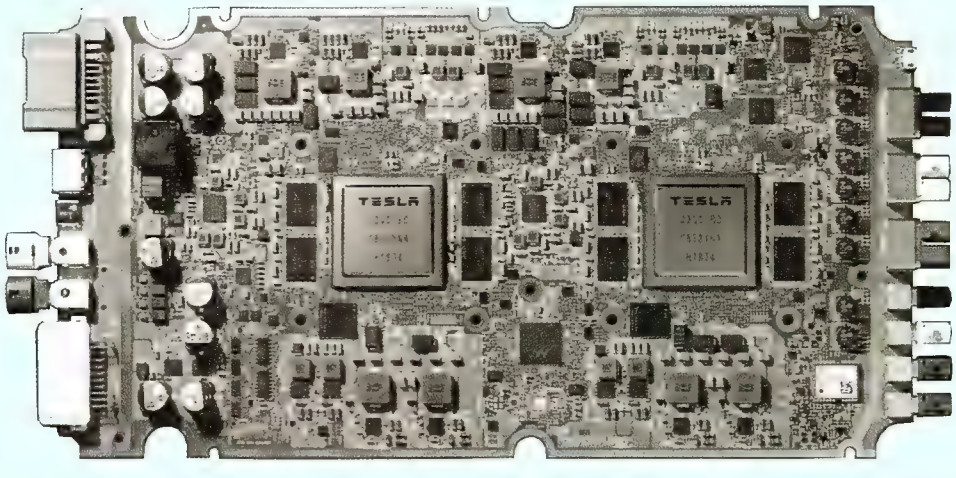
"In the beginning," Keller explains of the development of computers, "there was scalar math, like A equals B plus C times D. With a small number of transistors, that's all the math you could do." As the transistor count of computer chips grew exponential, so did the complexity of math that was possible. First, vector math was possible, then matrix multiply. Today, the complexity is pushing chip design in a new direction.

"As we get even more transistors, you want to take big operations and break them up. If you make your matrix multiplier too big, you begin to waste energy. So you build this optimal size block that's not too small, like a thread in a GPU, but not too big, like covering the whole chip with one matrix multiplier." The result, according to Keller, is an array of medium-sized processors where "medium" means a processor capable of four tera operations per second. What Keller is describing is the next step in AI computing from specialized blocks that accelerate matrix math, like Nvidia's Tensor cores, to a new type of chip that accelerates what he calls "graph" computing.

The other piece of the puzzle is software, an element Keller clearly views as just as important as hardware, and which he refers to as Software 2.0. "The first time I heard about Software 2.0 it was coined by Andrei Karpathy, who is the director of AI and autopilot at Tesla. His idea was that we're going from a world where you write programs to modify data to where you build neural networks and then program them with data to do the things you want. So modern computers are programmed with data. It means a very different way of thinking about programming in many places where AI has had so much success. I think in the Software 2.0 future, 90 percent of computing will be done that way," he says

The most fascinating of Keller's prognostications is the future unfathomability of AI computing. "If you go look inside a neural network that's been trained and ask why is this particular element given, say, the weight 0.0015843, nobody knows," Keller explains. "There's phenomena now where you have a machine learning system with inputs and outputs. There's an AI black box in between the inputs and outputs, but if you look in the box you can't tell what it means. You don't understand the math or the circuits underneath."

Keller concedes that already the full complexity of a high-end AMD, Intel, or Apple chip is almost unfathomable, but if you dig into any given detail, someone knows what it does. If Keller is correct, it won't be long before 90 percent of computing is beyond the wit of man. Whether it's intelligent is another matter.



Tesla's custom Autopilot chips are just one of many achievements in Jim Keller's stellar back catalog.

GPT-3 goes beyond the usual question-and-answer Turing Test tricks. It can do things such as build web layouts using JSX code in response to natural language requests. In other words, you type something like "build me a page with a table showing the top 20 countries listed by GDP and put a relevant title at the top," and GPT-3 can do just that. It showcases both the ability to adapt and a system that's based on processing data rather than intricate hand-coded rules.

However, GPT-3 is also a case study in the limitations of machine learning. Indeed, it's debatable whether GPT-3 is actually intelligent at all. Arguably, it could all be considered something of a digital conjuring trick. That's because GPT-3 and its machine-learning natural language brethren do not understand language – or, ultimately, anything else – at all. Instead, everything they do is simply based on statistics and patterns.

By analysing enormous quantities of written text, statistical rules that output plausible responses to natural language queries can be created without any need for what, on a human level, would be classed as understanding. And that, essentially, is the basis for most – if not all – machine learning, whether it's applied to the problem of natural language processing and voice assistants, self-driving cars, facial recognition, or recommending products and content to customers and consumers. It's just pattern spotting on an epic scale. From Amazon's Alexa to Tesla's Autopilot, the fundamental approach is the same. You can find out more about the limitations of existing AI systems in the boxout on the facing page, but if we've established the rough parameters of AI, the next question is how it's implemented and what kind of hardware is required.

Hardware requirements

At one end of the scale is what you might call AI infrastructure, the supercomputers and cloud installations used to do the epic data analysis and generate the pattern maps or models. At the other? Client devices that use those models in practical applications.

It's the latter that's of most interest to us as PC enthusiasts. Put another way, the question this all begs is whether AI is a clearly identifiable computing paradigm that benefits from dedicated hardware in client devices such as PCs and phones. Does it mean anything to have something akin to "AI compute cores" or specific parts of a chip expressly designed to accelerate AI applications? Or is AI on the client level largely marketing spin?

For sure, chips from the big players in computing are increasingly sold on the strength of their AI prowess. The most obvious example on the PC is Nvidia's graphics chips. For several generations now, Nvidia's GPUs have claimed specific AI capabilities thanks to a feature known as a Tensor core. First seen in Nvidia's Volta GPUs for enterprise applications and then in the Turing family of gaming GPUs, sold as the GeForce RTX 20-series, Nvidia's Tensor cores are now in their third generation in the Ampere GPUs, otherwise known as the GeForce RTX 30-series.

ON-DEVICE VS. IN THE CLOUD

What's the best way to process AI?

Ask anyone for a real-world usable example of AI and they'll probably pick one of the big three big digital assistants: Amazon Alexa, Apple Siri, or Google Assistant. But are such services better run locally on a device or up in the cloud?

Take Apple's iPhone. You might be surprised just how much of the familiar iPhone functionality is driven or at least enhanced by AI. It's used, for instance, to distinguish between intentional inputs and accidental brushes against the capacitive touchscreen.

Machine learning algorithms are also used to schedule charging, to improve long-term battery health, and to sort images in the Photo app into ready-made galleries and identify people using facial recognition. Depending on the age of a given iPhone, it may also be able to use machine learning to composite multiple images to create a single ultra-high quality photo. Even Apple's predictive text is enhanced by machine learning.

What's particularly interesting about Apple's approach to AI is how it fits into the contest between AI processed locally on devices compared to up in the cloud and in data centers. Broadly, Apple is moving away from cloud AI to on-device AI. Already, Apple has dedicated features like the Neural Engine in its chips that can be used to do things like image analysis locally on-device. In future, that approach will increasingly become the norm. The next iteration of Apple's mobile operating system, iOS 15, for example, will pull the processing for the Siri voice assistant out of the cloud and put it on to the iPhone handset.

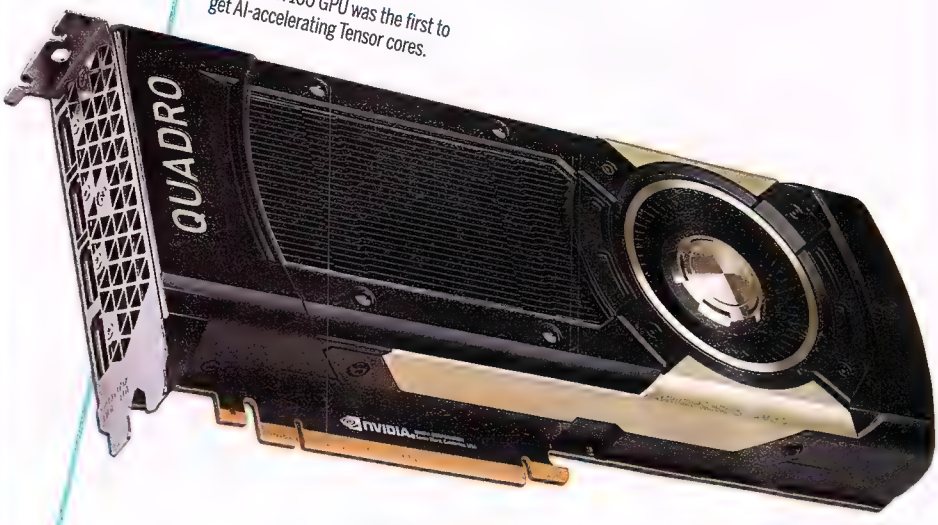
Partly, that's down to privacy concerns, which Apple sees as a major distinguishing feature between its products and services and the likes of Amazon, Google, and Facebook, which Apple argues all depend on knowing as much about you as possible.

"This addresses one of the biggest privacy concerns for voice assistants, which is unwanted audio recording," Apple said. But it begs the question of whether on-device AI can possibly compete with the huge machine learning models stored in data centers. Apple, predictably enough, says that it can.

"I understand this perception that bigger models in data centers somehow are more accurate, but it's actually wrong," says John Giannandrea, Apple's senior vice president for machine learning and AI strategy. "It's actually technically wrong. It's better to run the model close to the data, rather than moving the data around. And whether that's location data, like what are you doing, or exercise data, what's the accelerometer doing in your phone, it's better to be close to the source of the data. It's also privacy preserving."

Latency is another advantage of on-device AI. Over to Giannandrea: "You're taking a photograph, and the moments before you take a photo with the camera, the camera's seeing everything in real time. It can help you make a decision about when to take a photo. If you wanted to make that decision on the server, you'd have to send every single frame to the server to make a decision about how to take a photograph." That just doesn't make any sense, Giannandrea says. It's far better done on the device.

Of course, services that entirely depend on huge datasets will remain in the cloud for the foreseeable future. And given Apple's emerging stance on privacy, plus the company's undoubted prowess in developing both devices and the chips that power them, the on-device sales pitch definitely makes for a distinct proposition. But it remains to be seen whether consumers really care about privacy and if a Neural Engine or matrix math accelerator in an iPhone really compete with exaflops of dedicated Google AI hardware in a data centre.



Nvidia's GV100 GPU was the first to get AI-accelerating Tensor cores.

DLSS

The most familiar application for Nvidia's Tensor cores is its DLSS, or Deep Learning Super Sampling technology. It's a graphics upscaling implementation designed to deliver higher image quality while also boosting frame rates. The basic idea is to render a game engine at a lower resolution, say 1080p, to achieve higher frame rates, and then use DLSS to upscale the image to mimic the visual quality of a higher resolution, such as 4K.

The basic idea of upscaling isn't new. But instead of conventional spatial upscaling, DLSS is a temporal algorithm that compares the current frame to the previous frame, generating motion vectors that can be used to enhance image quality during upscaling. As it happens, DLSS is also a neat example of how AI infrastructure interfaces with client hardware.

DLSS is based on a supercomputer-powered per-game training process that compares millions of high-quality reference frames rendered at 16K (15,360 by 8,640 pixels) to scaled outputs, incrementally generating improved algorithms. Once the "training" process is complete, the DLSS scaling model for a given game is included in Nvidia's graphics drivers, then accelerated by the Tensor cores in Nvidia RTX graphics chips, allowing DLSS to be applied in real time to a running game engine.

And you know what? At its best, DLSS does things that other upscalers simply cannot achieve. Nvidia's arch-rival AMD recently released a more conventional non-AI alternative to DLSS, and while it works well enough, it lacks the magic of DLSS. Nvidia's AI upscaler isn't flawless, but it comes closer to convincingly mimicking native resolution rendering than anything else.

What's in a Tensor?

So, what exactly are Nvidia's Tensor cores and how do they differ from more familiar circuitry like pixel shaders in GPUs or integer and floating point units in CPUs? Is there really something specific about them that justifies the "artificial intelligence" angle?

In fundamental computational terms, Tensor cores accelerate matrix operations by performing mixed-precision matrix multiply and accumulate calculations in a single operation. These kinds of calculations are mathematically

By now, Waymo was expecting to have a fleet of at least 60,000 autonomous cars. It actually has 600.

THE LIMITS TO AI

This has all happened before...

Way back in the 1950s, at the dawn of computing, researchers assumed a machine with human-level intelligence might be possible within 10 years, 20 at the most. Here we are, 70 years later, and true AI arguably isn't any closer to reality. So, should we file AI along with a cure for cancer and nuclear fusion as yet another technology that somehow recedes from reach with every step forward in understanding?

Certainly, the limitations of current pattern-spotting machine learning are becoming increasingly apparent. In 2015, Elon Musk, Tesla's head honcho among his other accolades, confidently predicted self-driving technology would achieve "complete autonomy" by 2018. He wasn't alone in making that kind of bold prognostication. In 2016, Ford predicted that it would be selling "fully autonomous" commercial vehicles for ride sharing applications by 2021.

But here we are and driverless cars feel no closer to reality than they did a decade ago. Arguably, the challenge feels even greater. Earlier this year, John Krafcik, chief executive of Google's driverless car subsidiary Waymo, underscored the difficulty of developing driverless technology.

"It's an extraordinary grind, a bigger challenge than launching a rocket and putting it in orbit around the Earth because it has to be done safely over and over and over again," Krafcik said. That's quite a turn around from 2018, when Waymo was planning to unleash 62,000 driverless minivans by the end of that year. At last count, Waymo's driverless fleet numbered just 600 vehicles.

"When we thought, in 2015, that we would have a broadly available service by 2020, it wasn't a crazy idea," Krafcik explained. "If we've got one prototype, then we can get to mass production in just a couple of years, right? This was a position of – I wouldn't say ignorance – but a lack of information and a lack of experience. We've become very humble over these last five years."

Self-driving car technology is not the only area where the promise of AI has failed to deliver. Far from it. The Economist magazine reckons enthusiasm for AI across industry is stalling, in part due to being overhyped, citing a survey of European AI start-ups that found 40 percent were not actually using AI at all.

More broadly, The Economist reckons AI faces two core problems. The first is, surprisingly, a lack of data. Despite our increasingly digitised lives, critical data is often incomplete. Tracking COVID-19 transmission without a comprehensive record of individual movements, for instance, has proved impossible.

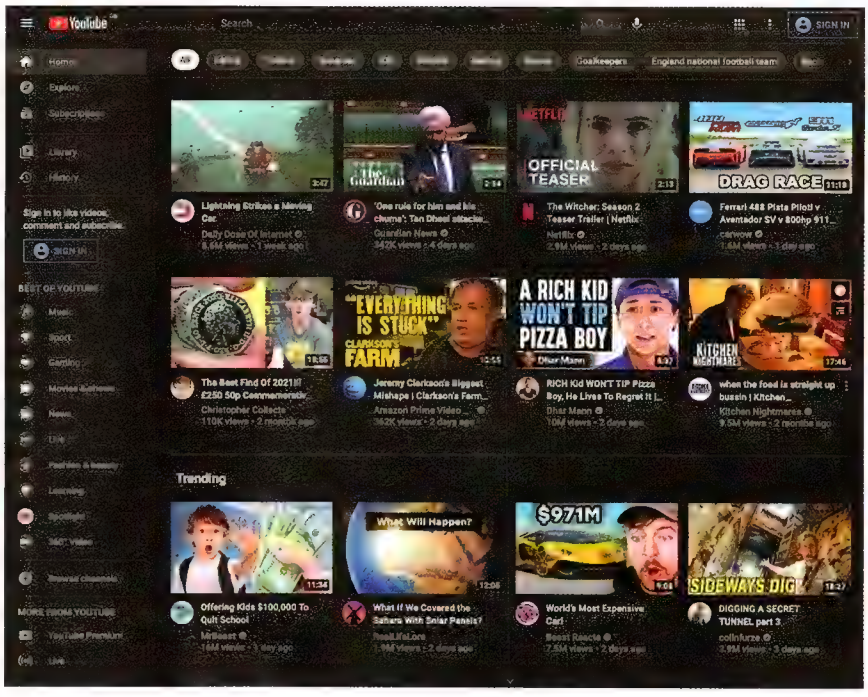
The second problem is even more challenging. Existing AI typically depends on pattern spotting and does certain tasks like image recognition and language processing far better than old-school software with hand-coded rules. But such systems are not "intelligent" as the term is traditionally understood. There's no cognition or reasoning, no ability to generalise, just a narrow ability to do one thing very well. In fact, the scope of existing AI systems is so narrow there is now doubt whether fully autonomous cars will ever be possible, such is the complexity of coping with the unpredictability of driving in the real world on real roads – and even slightly off them.

straightforward, but computationally intensive on general-purpose computing architectures, such as CPU cores. The "Tensor" branding, for the record, is an appropriation of the mathematical term of the same name that refers to containers of data of which matrices are a subset, and also includes scalars and vectors. Scalars can be thought of as zero-dimensional tensors composed of a single number, vectors are a one-dimensional tensor composed of a single column of numbers, and matrices are two-dimensional tensors made up of both rows and columns of numbers.

Modern CPUs do have floating point units with SIMD or single instruction multiple data extensions designed, among other things, to accelerate calculations involving matrices. But that hardware remains multipurpose rather than purely dedicated to matrix math. Highly parallelised GPUs are even better at crunching matrices, but even they employ broadly programmable units, such as Nvidia's CUDA cores, that are not narrowly and exclusively designed for matrix math.

Except, of course, Nvidia's Tensor cores. Nvidia's GV100 chip, as found in the Titan V graphics card, was its first GPU with Tensor cores – 640 of them to be precise, rated at 110TFLOPS. By way of comparison, the GV100 also has 5,120 of Nvidia's conventional CUDA cores, which can also do matrix math. The combined computational output of those CUDA cores comes to just 27.6TFLOPS, despite being far more numerous and eating up the majority of the die space on the GV100 chip. When it comes to matrix math, then, Tensor cores are orders of magnitude more efficient.

What's more, the matrix math performance of Nvidia GPUs is growing fast. At one end of the scale, the GeForce RTX 3060, currently the lowest-end RTX 30 series GPU available, roughly matches the GV100 in terms of Tensor core performance. Meanwhile, Nvidia's latest high-end enterprise GPU, the A100, has around triple the Tensor core performance. As it happens, the A100 chip is the basis for Nvidia's Perlmutter supercomputer, claimed to be the world's fastest AI machine. Created in partnership with HP, it packs no fewer than 6,159 A100 GPUs, delivering nearly four exaflops of compute power, a number so huge that it's difficult to, well, compute.



It might not always feel like it, but recommendation engines, such as that used by YouTube, are powered by advanced AI.

The upcoming Sapphire Rapids architecture for Xeon server chips will be the first to get Intel's AMX matrix math acceleration extensions.

Digital assistants such as Amazon Alexa are what probably spring to mind when thinking about existing AI applications.

Intel, Google, and Apple

Anyway, AI-specific logic in chips from Nvidia's competitors is also all about matrix math. Intel's upcoming Sapphire Rapids Xeon processor for servers, for instance, packs what Intel is describing as a new "built-in" AI acceleration engine called Intel Advanced Matrix Extensions, or AMX for short. For now, Intel isn't giving away much by way of specifics. But it's thought that AMX essentially amounts to a matrix math overlay on top of Intel's existing AVX-512 vector engines.

Coincidentally, Apple has its own matrix-optimised AI blocks in its in-house chips, beginning with the A13 SoC in the iPhone 11, and revised for the new A14 and M1 chips, the latter found in the latest MacBook Air, entry-level MacBook Pro, Mac Mini, and iMac. Those blocks are also dubbed AMX, although in this case that refers to "Apple Matrix," as opposed to Intel's Advanced Matrix Extensions. Actually, Apple's chips confusingly have yet another AI-accelerating block, known as the Neural Engine. For more on that and the broader concept of neural networks, head for the boxout on the right.

Meanwhile Google's TPU, or Tensor Processing Unit, which is a whole chip dedicated to matrix or tensor math, is now on its fourth generation, having debuted in 2015. Granted, the Google TPU is not something you'll find in your PC or phone, but it's another example of how the computing industry is converging around a common approach to AI acceleration, and confirmation that AI is a meaningful computing paradigm, not merely a marketing term. Google says those TPUs, incidentally, were used to identify and process all the text appearing in its entire StreetView database in Google Maps in under five days.

Overall, AI presents an intriguing dichotomy. On the one hand, there is no doubting the huge impact it is having on computing and in turn the way we live our lives. AI and machine learning can do things no other computing paradigm can match. On the other, it's hard to dispel the sense that it's misdescribed. Machines can certainly learn to do some seemingly clever things, but it's debatable if there's any true intelligence involved. If it isn't, if all this really is purely pattern spotting, AI may be destined to remain siloed into narrow if ever more numerous competencies, the full promise and peril of a more generalised artificial intelligence tantalisingly out of reach. ■

NEURAL NETWORKS

The low-down on deep learning

Computer scientists have been dabbling with neural networks since the 1950s. Back then, researchers in the field predicted the technology would lead to machines capable of walking, talking, consciousness, and even self-replication. If that seems like a stretch, there's no doubt neural networks are now one of the most important elements of the broader AI effort. But what are neural networks, how do they work, and what are they used for?

Neural networks are a type of data structure loosely inspired by networks of biological neurons, where the digital neuron is a mathematical function involving weighted sums. The larger an input's weight, the more that input affects the neuron's output. The clever bit is the network's ability to "learn."

Using the example of image recognition, if the network of neurons correctly classifies an image input, the weights used to achieve the correct identification output are increased and vice versa, incrementally improving the ability of the network to correctly identify images. The problem, in those early days of neural networks, was the available computing power.

The big practical breakthrough came with the ability to dramatically increase the "depth" of trainable layers in the network. Enter the notions of deep learning and backpropagation. Very long story short: The use of multiple layers of inputs and outputs, the "deeper" the better, each feeding or propagating back into and improving the accuracy of the layers below, radically expands the scope of trainable networks.

An early example of this approach came in 1998 when it was used by researchers at AT&T to recognise hand-written numerals and thus automate the process of paying in checks. As the researchers concluded, the approach using automated learning yielded far better results than "hand-designed heuristics."

As the availability of compute power has exploded, so the applicability of deep learning neural networks has expanded. By 2013, Google was using it at the core of its online image search and it has since been rolled out for everything from smartphones to smart cars. But perhaps its greatest attribute is the ease with which it can be applied. Over the last few decades, the building blocks of neural networks have been fine-tuned, making the training relatively straightforward given sufficient quality data. All of which implies that the future of AI is as much and maybe even more about access to data as improved algorithms.

Want to experience the power of neural networks? You probably already have done, courtesy of Google's image search.

FEATURE

Games of the Decade

The last 10 years have really pushed gaming to new frontiers; Ian Evenden highlights the most important games of the 2010s

The last decade was something of a golden age for PC gaming. It saw the gap between consoles and gaming PCs widen even further, as the hardware we play on became more powerful and capable than ever before.

But it also saw the emergence of the blockbuster game as a rival to the kind you see in theaters. In 2007, 14 years ago, *Halo 3* took the largest launch-day sales of any media property at that time, with first-day sales of $230 million, overtaking the likes of *Harry Potter* and *Spider-man* at the movies. Since then, the numbers have only got bigger, and in 2017, *PlayerUnknown's Battlegrounds* took $1.2 billion on its first day, toppling 2013's *Grand Theft Auto V* ($1.1b).

GTAV – a game that launched on Xbox 360 and has appeared on three generations of consoles – is also emblematic of the past 10 years in gaming, as the decade has seen more in the way of remakes, remasters, and straightforward rereleases than at any other time. This doesn't mean that the game industry has become less creative, but it's a reflection of how much more expensive and intensive it has become to develop a triple-A, big-budget game in the years that saw the rise of ray tracing, the consolidation of multicore processors, and 4K screens become something you can pick up for a few hundred dollars. Development teams are now huge, budgets reach into the hundreds of millions, and games can be in development for many years before being released, unfinished.

Here, then, are our pick of the PC games of the last decade, in no particular order.

Released: 2013
www.rockstargames.com

GRAND THEFT AUTO V

Ridiculous fun, as long as you can square your conscience with playing the bad guy. Rockstar's satire on western society takes all the best things about *The Wire*, *The Sopranos*, and a dozen other box sets and sets them loose under a blazing sun, where they interact and self-destruct with gore-infested glee. Playing as three street-level characters up against governments and billionaires grounds the absurdity, while a never-ending multiplayer mode of hits and heists keeps players coming back.

Released: 2011 | https://elderscrolls.bethesda.net

THE ELDER SCROLLS V: SKYRIM

Ten years old, and still the most recent mainline *Elder Scrolls* release. Another game that's spanned console generations, picking up the *Special Edition* and modding it heavily is the definitive way to play on PC today. Modern hardware makes graphical updates that once brought GPUs to their knees fly, and it's still big enough to get lost in. Fighting giants and dragons while auroras whirl overhead is as vital today as it was at release.

Released: 2018 | www.rockstargames.com

RED DEAD REDEMPTION II

Rockstar slows down, makes a campfire, and contemplates the prairie. Then quick-draws, shoots six bad guys in the head, and helps a nice lady find some dinosaur bones. Less frantic than *GTA*, with a good line in character-driven action and some of the best sunsets we've yet seen, it was tough on PC hardware in 2018, and GPUs are only just catching up in 2021. A game of long horseback journeys punctuated by graphic violence, poker games, train robberies, and just about everything else you've seen in a Western, it feels, unusually for a videogame, as though it comes from a place of love.

Released: 2011 | https://store.steampowered.com

PORTAL 2

Evil robots, celebrity voice actors, and computers powered by potatoes may get in the way, but *Portal 2* is still the perfect example of game designers showing off how clever they are. And it's great entertainment. Along with the portal gun, which links two surfaces within the level, *Portal 2* adds colored gels that create or impede movement, but that's it. It still requires you to think in three-dimensional corkscrews, with level after level of lethal escape rooms often appearing deceptively simple but full of thought and planning. It's not a long game, but it stays with you.

Released: 2021 | www.ea.com

MASS EFFECT: LEGENDARY EDITION

It was 2007 when Commander Shepard first made contact, but the culture of remakes has brought him (or her) around again, with a graphical upgrade and three-for-one (plus DLC) pricing model, and these RPGs mixed with a heavy dose of third-person shooter are still better than many released since. The first game is a tight, focused introduction, but the second opens out to envelop a whole galaxy under threat. It's improved by what it's lost – unwieldy vehicle sections and annoying weapon specialisations have been cut, as has multiplayer – as much as by what it's gained (the trilogy's ending is the controversial *Extended Cut* version), and if you've not played before is an absolute steal.

Released: 2010
www.blizzard.com

STARCRAFT II

Technically just a little too old to be here, but the final mission pack (*Nova Covert Ops*) was released in 2016, and the entire game is simply awesome. With three beautifully balanced races – brutal mechanised Terrans, advanced psychic Protoss, and swarming insectoid Zerg – each with a full single-player campaign, and some of the best strategy multiplayer in the business, they don't make 'em like this any more, and that's a shame.

Released: 2011
www.minecraft.net

MINECRAFT

The game that sold 200 million copies and captivated even more kids is a bizarre mix of Lego and a rock-hard survival game. Get your walls built before nightfall or the zombies will get you. The creative side far outweighs the survival gameplay, however – there's nothing like it for building floating castles – and it's still getting updates, with the last major one in 2020 adding new biomes, resources, and monsters. Not just for kids.

Released: 2015
https://thewitcher.com

THE WITCHER III: WILD HUNT

A beautiful, dark fantasy, open-world RPG, it was *The Witcher*'s stories that drew, and continue to draw, players in. Your attention is pulled this way and that as you try to follow missions but get waylaid by villagers asking you to kill the neighborhood monsters, and a political story bigger than anyone plays out around you. The expansion is particularly good for this, and is bundled in the *Game of the Year* edition.

Released: 2018
https://forzamotorsport.net

FORZA HORIZON 4

The PC has a lot of racing games, and *Horizon 4* may not be the most accurate in terms of simulation, but for sheer freewheeling entertainment, it's hard to beat. Set in an England apparently unaware that a major racing tournament is taking place on its roads and across its fields, *Horizon 4* mashes together online and offline play, and has you compete in varied events across four very different seasons to build "influence," which you use to unlock new events, and so on. It also releases weekly events, hides rare cars in barns, rewards you for ludicrous combo jumps, and generally makes it impossible to get bored.

Released: 2011 | www.warnerbrosgames.com

BATMAN: ARKHAM CITY

Rocksteady's Batman doesn't mess around. He's crunchingly physical, the only way to deal with crime being with his fists and boots. The middle game in a trilogy, *Arkham City* takes the focused violence of *Arkham Asylum* and roots it in a free-roaming city, *Escape From New York*-style, meaning you can zip around the rooftops doing puzzles and platform challenges before silently descending and devastating your foes.

Released: 2013 | https://2k.com

BIOSHOCK INFINITE

A flying city full of racists, robots that look like presidents, sharks jumped, and fridges nuked. *BioShock Infinite* is a lot of surface stretched over some thin scaffolding – the repetitive nature of the arena battles soon becomes apparent – but if you don't peer too deeply and try not to care that nothing makes sense, it's an atmospheric and artistically unrestrained romp through unfriendly skies.

Released: 2017 | https://divinity.game

DIVINITY: ORIGINAL SIN II

The closest thing we've yet seen to tabletop RPG gaming on a computer, your PC plays the DM with a smirk, letting you try just about anything you like, and ruling fairly on whether you will succeed. So, if you want to eat corpses, there's a class for that, and if you want to use the teleport skill to essentially cheat, well, you can do that, too, as long as you make the dice rolls. The best thing since *Baldur's Gate II*.

Released: 2016 | https://playdead.com

INSIDE

There is no other game in which you can pull an eel out of the backside of a pig, and for that alone *Inside* deserves to be on this list. The story of a frail boy on the run from ruthless, murderous, law enforcement, it quickly transforms into a mysterious stealth adventure in which nothing is adequately explained. The ending, a roaring, cathartic reversal of everything that has gone before, is worth the multiple deaths it will take to get there.

Released: 2017 | www.epicgames.com

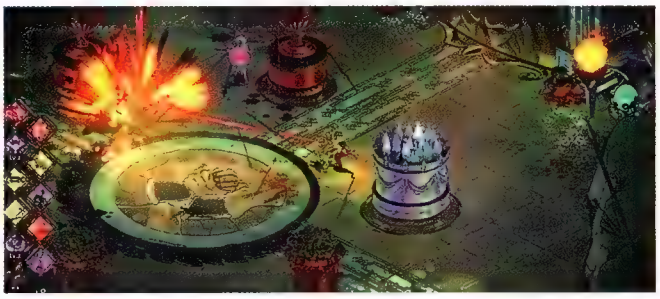
FORTNITE

Shooting zombies, and each other, while laying traps is the essence of *Fortnite*, each match opening with a period of scavenging before building a massive base you have to defend. Having the high ground is a big part of combat, so harvesting material and building like a mad gopher will get you a long way. There are skill trees, constant content drops, and a permanent state of progression by the tiniest fractions of an inch. Battles have 100 players, and while it's possible to play for free, you'll get much more in the way of a reward if you buy a Battle Pass.

Released: 2013 | www.dota2.com

DOTA 2

This retail release based on a *WarCraft III* mod was used to get Steam into places it hadn't gone before, so the free, 5v5 arena battler ended up with huge player numbers. The idea is to lay siege to the enemy base by picking one of 112 heroes, having an appreciation of the advantages of each and how it will team with the other four players on your side. It makes 4D chess look easy.



Released: 2020 | www.supergiantgames.com

HADES

Zagreus, son of the Greek god of the underworld, wants out. This is not going to be easy, however, as every lost soul and mythical monster stands in his way. You repeatedly try to leave the underworld only to be beaten, return to the start, become more powerful, talk to your dad and pat his dog, then try again. It's wonderfully written and the combat hits just right.

Released: 2019 | www.remedygames.com

CONTROL

The Oldest House is a New York skyscraper with a secret, and you just walked in off the street into the middle of it. An extradimensional intelligence is trying to enter our universe through a slide projector, and as Jesse Faden picked up a weird gun at the beginning of the game, the building has decided it's up to her to stop it. A *Metroidvania* that involves plenty of backtracking and unlocking of new areas, you'll soon be flying, telekinetic, and in possession of an eldritch grenade launcher. There's nothing like it.

Released: 2012 | https://bethesda.net

DISHONORED

A strange, steampunk setting and some of the lumpiest faces in gaming make *Dishonored* stand out from the crowd – if there was a crowd of games like this. Part *Hitman*, part *Deus Ex*, all weird, you play a supernatural royal bodyguard trying to restore order to his city. Leave bodies everywhere and the game gets harder, so slipping through unnoticed is key; that's easier said than done.

Released: 2018 | www.ubisoft.com

ASSASSIN'S CREED: ODYSSEY

In one of the defining series of the decade, *Odyssey* remains one of the better sneaky-RPG games ever made. Not only is the world huge, but it's filled with things to do, and the Mediterranean sunshine makes it an engaging place to do your killing. The first *AC* game to offer a choice of characters, its plot runs from the mundane to the mythical in a lively, dynamic world.

Released: 2014
https://en.bandainamcoent.eu

DARK SOULS 2

The best of the three, at least until *Bloodborne* gets its inevitable PC release, and the PC port (*Scholar of the First Sin*) looks much better than the console games ever did. Alongside the famously hard bosses and clanging combat, there's a real sense of exploration in a world that's far from open. You're pushed in a direction, despite being able to fast travel and return to a hub, and the game is better for this. You always know something terrible is coming, so you edge forward behind your shield the first time, before getting more powerful and confident as the game goes on.

Released: 2014 | https://bethesda.net

WOLFENSTEIN: THE NEW ORDER

This could have been *Doom*, but the first new *Wolfenstein* game since 2009 has something special. MachineGames takes the setting into a Nazi-dominated 1960s, piles on the retrofuturism, and literally takes you to the Moon and back. The combat is ferocious, the guns and enemies suitably over the top, and Blazkowicz is more than just a smirking bullet-sponge.

Released: 2014 | www.bungie.net

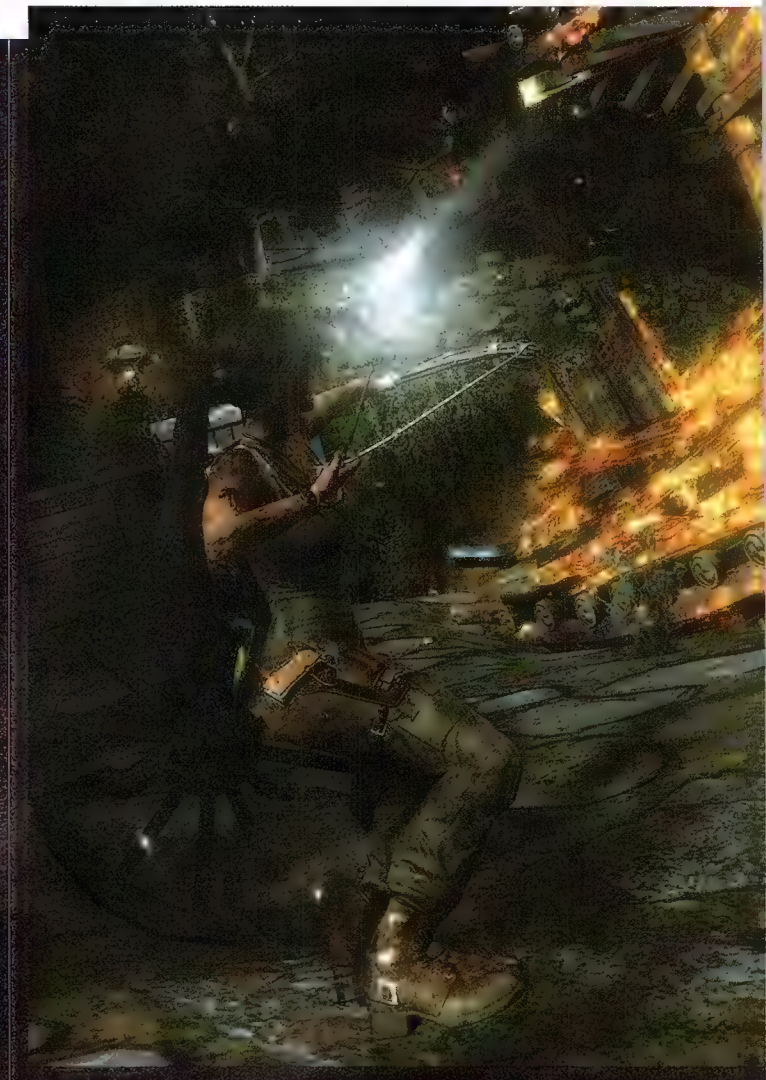
DESTINY

What is *Destiny*? An online sci-fi first-person shooter in which you perform the same actions again and again in a constant search for better equipment for your class-based character. The action has moved to *Destiny 2*, and new content drops fairly regularly, while PvP arena combat keeps your skills sharp. For a long-running online shooter it's easy to pick up and start playing.

Released: 2016 | https://xcom.com

XCOM 2

XCOM has lost its battles against the alien invaders, who have taken over Earth and are creating alien/human hybrids. You no longer have to make the bickering nations of the world happy, you just have to put bullets, lasers, and plasma into alien faces, rescue kidnapped scientists, dig out new sections of your base, and discover where the alien commanders are hiding. The heart of the game is the precise turn-based combat, in which cover is everything, having the high ground can be the difference between victory and a total wipe, and a 95 percent shot can miss.



Released: 2013 | https://tombraider.square-enix-games.com

TOMB RAIDER

The beginning of a trilogy that failed to build high on these solid foundations, the reimagined *Tomb Raider* is perhaps the best refresh of a well-known character we've seen, showing Lara Croft at the start of her career, taking away the sexualization, and leaving a delicate girl just as likely to shake and whimper as she is to pepper an enemy with rifle fire. She grows into a mass murderer, but takes her first kill hard, and even when forced to hunt deer for food, she clearly feels every death deeply. It's an interesting character portrait as much as an acrobatic shooter.

Released: 2013 | http://kentuckyroutezero.com

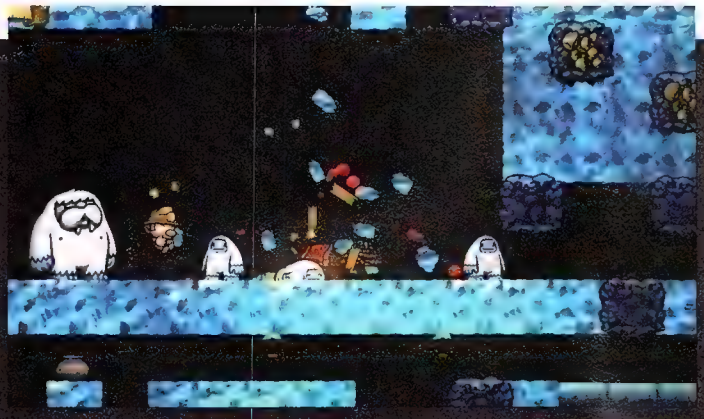
KENTUCKY ROUTE ZERO

Another magical-realist title that's about the characters you meet rather than shooting them; you're not having much of an effect on this linear world, just drinking in the sort of working class stories you rarely see in videogames. The greatest sights are saved for the moments when new characters join your group, all looking for something that may not even exist.

Released: 2019 | www.metrothegame.com

METRO: EXODUS

Gaming's most claustrophobic series busts out of the Moscow sewers and into brilliant, ray-traced sunlight as you search for the source of a transmission that was previously jammed. While it loses some of its character by coming out of the dark, you still sneak around plenty, using pneumatic weapons to silently kill slave masters, mutants, and enormous bat-things.



Released: 2013 | https://spelunkyworld.com

SPELUNKY

A remake of a 2008 freeware original, this game of procedurally generated cave exploring and shotgun-archaeology is a highly accessible roguelike. There's permanent death on offer, and the difficulty level is high, but the rewards are great, even if that's just satisfaction gained by not dying for a while. No two trips are the same, so once you've played for hundreds of hours, you'll see the game's blocks and creatures everywhere you go.

Released: 2019 | www.halowaypoint.com

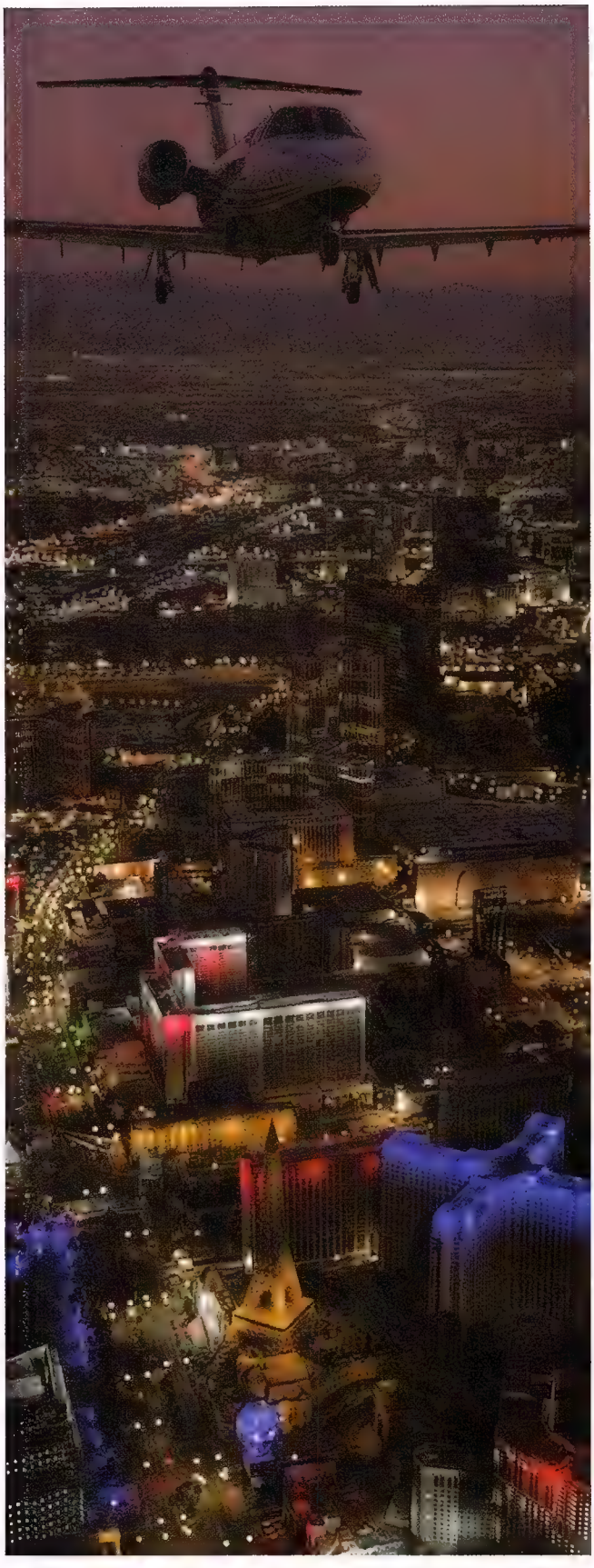
HALO: THE MASTER CHIEF COLLECTION

A slight cheat, as each game here except *Halo 4* was released before 2012, but they're some of the best sci-fi shooters ever. You get upgraded graphics and netcode, with complete redesigns of the audio and cutscenes. What's not changed is the shooting, AI, and handling, so the starting pistol is still the best weapon, and on higher difficulties, the Elites still put up a good fight. There's still the Flood and the Library, but that's only one part of one game.

Released: 2019 | https://discoelysium.com

DISCO ELYSIUM

A point and click! In 2019! Waking up on the floor of a hotel room minus your pants and nursing a hangover so bad you can't remember who you are, this strange police procedural casts you as an amnesiac cop with a murder to investigate. It's as much about putting yourself back together as it is investigating the chap hanging from a tree. You can choose a new name, and the way you respond to the people you speak to molds your new personality.



Released: 2020

www.microsoft.com

MS FLIGHT SIMULATOR

Is it even a game? In these troubled times, the kind of clear headspace attainable from simply flying a plane through calm, sunny skies is the sort of service we should probably be paying 10 times as much for. It needs some strong hardware, but the live air traffic control chat, streaming map-based landscapes, and real-time weather effects add up to something that is exactly as realistic as you want it to be, and sends you off with a huge sense of achievement once you pull off one of the trickier maneuvers. Like landing. ■

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SATA AF

The ultimate Backup Guide

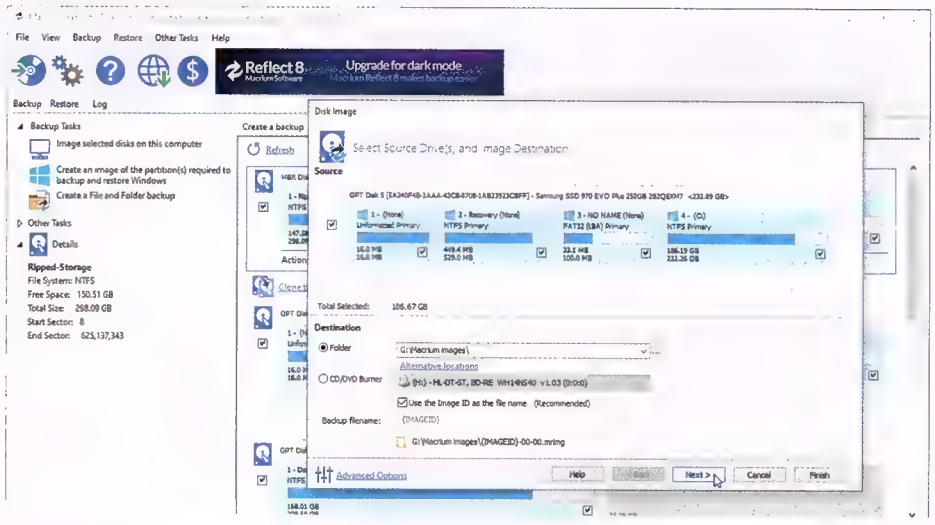
How safe is your data? Nick Peers reveals how to set up a foolproof backup plan.

Have you ever suffered the crippling sensation of data loss? Found yourself having to reinstall Windows from scratch and realising just how many apps and settings have been lost? The importance of backups cannot be overstated, but does your current backup plan cover all the bases? Is it comprehensive, frequently updated, and spread across multiple locations?

In this feature, we reveal the best free tools for the job, from taking a fail-safe backup of entire hard drives to protecting multiple versions of your data files, so you can undo unwanted changes in addition to protecting the files themselves. We also recommend what to look for in backup devices, and how to safely store your files in the cloud without potentially exposing them to third parties.

Crucially, we step you through the process of backup and restoration, and reveal tools and tips to plug any remaining gaps in your armor. Are you ready to ensure you never suffer another data loss nightmare? Turn the page to get started...

We've broken down the backup process into three key stages. First, you need to take a full, fail-safe drive image to protect everything on your system drive, from your Windows installation and programs to your app settings and any files on the drive. Then you should make a separate, independent backup of your personal data, those files and folders that are irreplaceable, from precious photos to crucial work documents. Finally, we help you securely back up files to your cloud storage while retaining full control of the encryption keys that protect them from unauthorised access.



Macrium Reflect can back up to local and network drives.

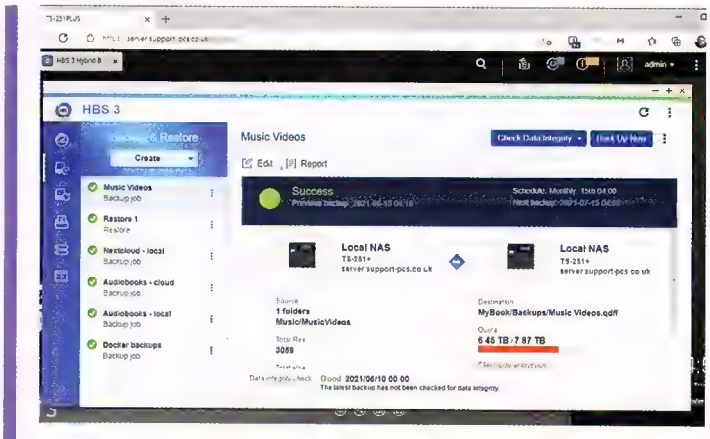
Step 1:
Take a full backup

Your first backup will be your most thorough: a byte-for-byte copy of your hard drive in the form of a drive image. This serves a multitude of purposes. Firstly, it's comprehensive. Secondly, it provides you with a working copy of Windows, your programs, and – if everything's on the same drive – your data, so you can roll your PC back to a recent working state in the event of disaster.

You need one or more backup drives that are big enough to not only contain a complete – albeit compressed – copy of your main hard drive, but all subsequent backups, too. To minimise the amount of space these backups take, it's important you choose a drive imaging tool that's capable of taking multiple snapshots of your system in such a way as to consume a fraction of the space they'd normally require.

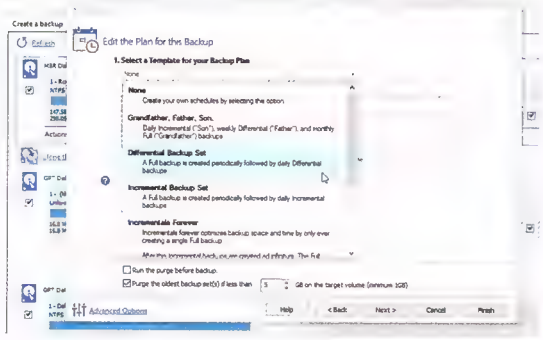
The tool in question is Macrium Reflect Free (**www.macrium.com/reflectfree.aspx**) and it uses what's known as differential backups to reduce the amount of space your backups consume, making it practical to store weekly or even daily snapshots of your system. Differential backups require one full backup, then they simply record all the changes to your system made since that full backup was taken, resulting in a significantly smaller file (try 10–20GB instead of 120GB, for example). As an added bonus, differential backup jobs complete faster than full ones.

Because each differential backup is based on the latest available full backup, they grow as time passes and more changes are made to your system. The solution is to adopt a set of rolling backups known as a father-son set. You create a fresh full – or father – backup on a monthly basis, then take differential (son) backups on a weekly basis. To save space, the job retains only a set number of



Your NAS drive may offer additional backup options.

Use a template to schedule regular backups.


Create a backup
Edit the Plan for this Backup
1. Select a Template for your Backup Plan
None
Create your own schedules by selecting the option
Grandfather, Father, Son.
Differential Backup Set
A Full backup is created periodically followed by daily Differential backups
Incremental Backup Set
A Full backup is created periodically followed by daily Incremental backups
Incrementals Forever
Run the purge before backup.
Purge the oldest backup set(s) if less than
Advanced Options
Help
< Back
Next >
Cancel
Finish

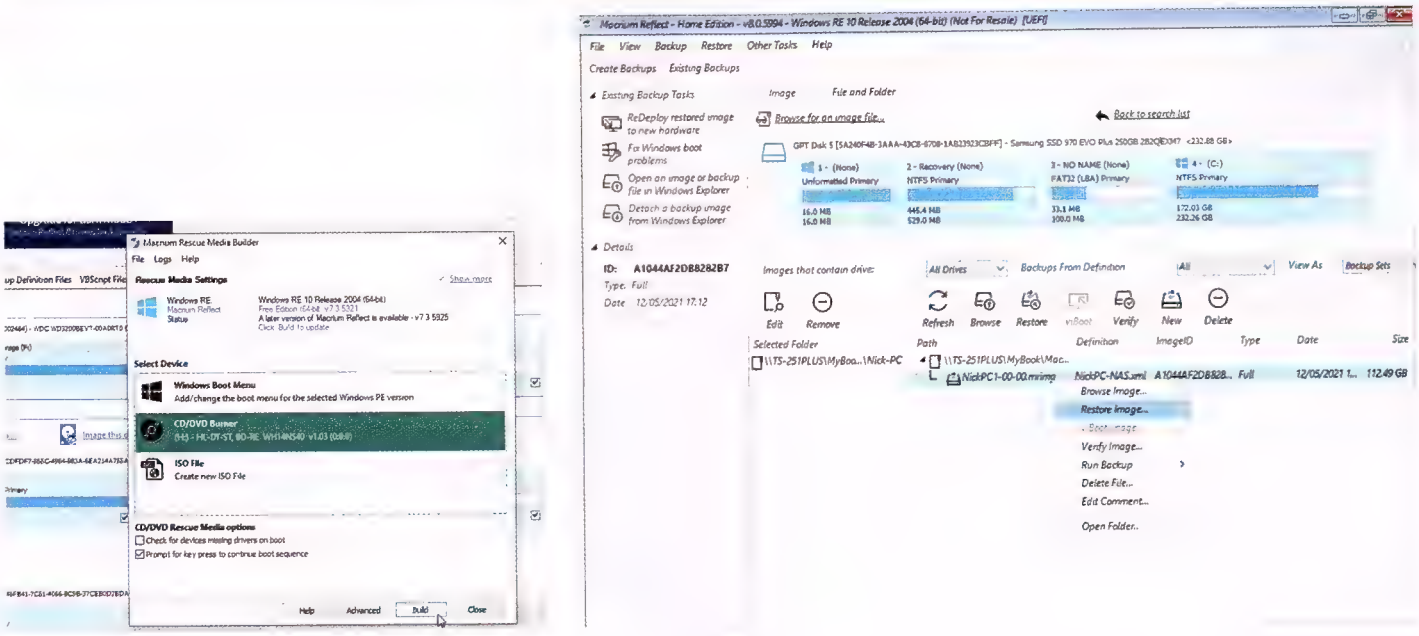
INVEST IN BACKUP DEVICES

You can never have too many backup devices. A rule of thumb is to back up to a minimum of two physically separate drives or locations, and if you have cloud storage, store at least your most critical files online, too (ensuring they're as secure as they can be).

The cheapest backup option is a secondary hard drive – whether internal or connected via USB, it's quick and convenient, but vulnerable to the same fire, damage, or theft as your main PC. With prices slowly tumbling, select the largest drive you can afford (4TB costs around $130) to meet your backup needs both now and going forward.

Ideally, your second backup drive should be in a different room – if not off-site – to provide additional protection against physical threats. Look for a network (NAS) device that can serve as a central backup location for all the computers in your home.

Look for models with two or more drive bays, enabling you to expand capacity or provide additional redundancy in the form of RAID. Models like QNAP and Synology are more like mini-servers than simple network storage devices, giving greater scope to run centraliaed services such as NextCloud, as well as offering their own tools similar in scope to Duplicati.



backups: typically, two to four full ones, depending on available storage space, then a rolling set of four to five differential backups.

If space isn't an issue, you could take weekly full backups then daily differential ones, but this obviously consumes more space and you'd have to strike a balance between number of backups and how far back you might want to roll your PC.

Alternately, try the Home Edition of Macrium Reflect (US$69.95), which also supports incremental backups; each incremental backup merely records the changes made since the last backup was taken (whether it's full, differential, or incremental), rather than relying on a full backup each time. This allows you to implement a grandfather-father-son schedule: monthly full backups, weekly differential, then daily incremental. For more on Macrium Reflect Home – including a new intra-daily backup feature in version 8 that creates incremental backups every 15 minutes – see our head-to-head on page 36.

Above: Don't skip the prompt to build your rescue media.

Above right: You can restore from within Windows in minutes.

Upgrade to Macrium Reflect Home for more features.

Set up a schedule

How does Macrium Reflect work? First, launch it. If all your files are stored on a single partition (typically drive C) or you're only interested in taking a drive image of your system, click "Create an image of the partition(s) required to backup and restore Windows."

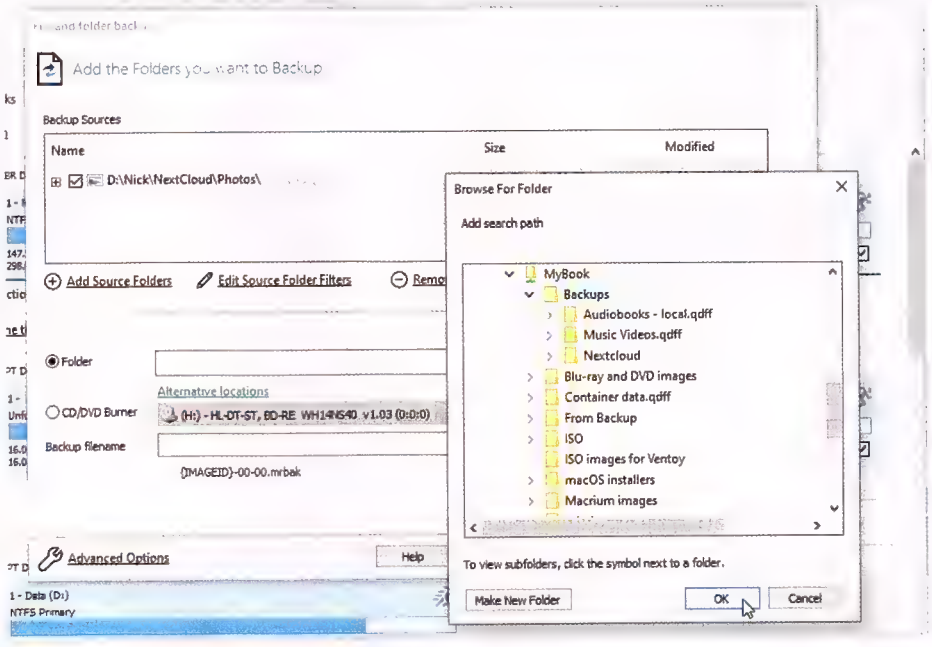
Next, choose where to store your backup. Click "…" next to "Folder" to select a folder on a backup drive (see the box opposite). You can also select a network drive from here – if it requires user/password credentials that aren't stored in Windows, you need to cancel the backup job and choose "Other Tasks > Edit Defaults." Switch to the "Network" tab and click "Add" to select the destination, then enter the credentials so Macrium can seamlessly connect when required. Once done, click "OK" twice and restart the process.

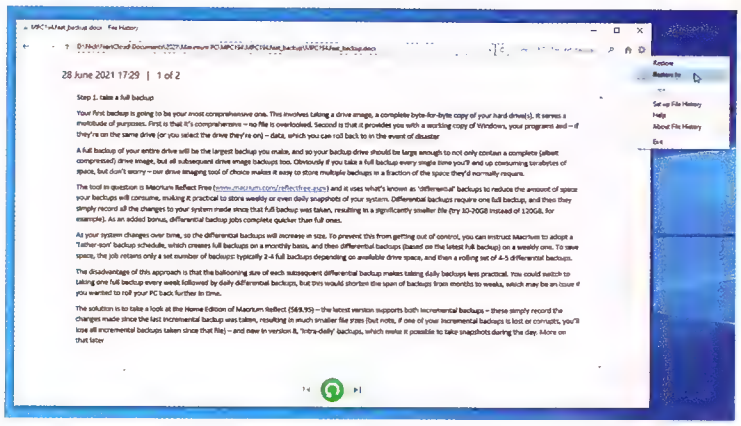
If you're relying on a backup destination that isn't always available, such as rotating external backup drives that aren't constantly plugged in, click "Alternative locations" to choose each location in the sequence you'd like them to be used. Note: If you intend to back up to two separate locations, ignore this, as you need to set up individual jobs for each backup drive.

Now click "Advanced Options" to tweak various settings. The "Password" option requires a Home license if you'd like to encrypt your backups, but one recommended tweak is to check the box under "Auto Verify Image" to ensure your newly created backup is validated immediately after it's created.

Once done, click "OK" followed by "Next" to set your backup schedule. You can manually set it using the controls if you want to pair one monthly full backup with weekly differential backups; if you're going for daily differential backups, click the "Template" drop-down and choose "Differential Backup Set" or select the "Grandfather-Father-Son" template if you've purchased a Home license. Then use the "Define Retention Rules" section to determine how long each type of backup is kept (either a set number of backups, or in days or weeks).

Finally, click "Next" then "Finish." Leave both boxes checked, give your backup job a suitable name and click "OK" to take your first backup. Once complete, move on to set up your second backup job if – as we recommend – you're creating a secondary backup for extra redundancy: Create a new job and repeat the steps above, pointing it to your secondary drive and tweaking the timings so it doesn't clash with the main backup.





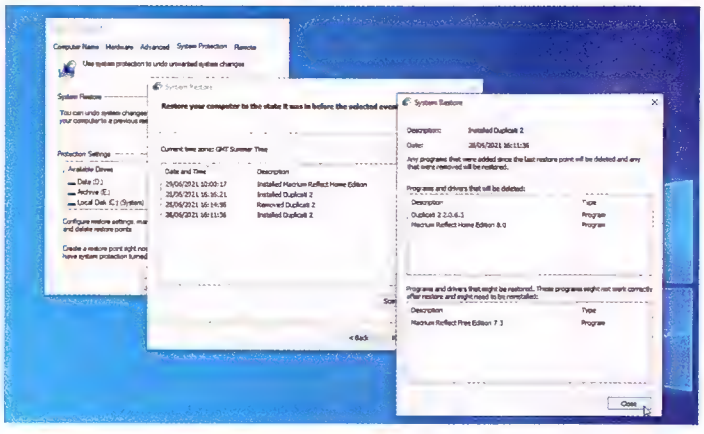
File History enables you to preview files before restoring them.

Your next job is to create rescue media – if Windows ever fails to boot, you'll need this to restore your system. If you've not yet been prompted to by Macrium, choose "Other Tasks > Create Rescue Media" to do so. You can burn a DVD, use a USB flash drive (our preferred choice), or add an option to load the rescue environment from the Windows boot menu.

Restore your drive images

Disaster has struck and your PC either won't boot or your hard drive has just died. No matter – if necessary, fit the replacement and reach for your Macrium rescue media. Boot from this and you'll find yourself at a replica of the main Macrium user interface on the "Restore" tab. It should scan your drives for backups, enabling you to choose the one you want (typically the most recent version), or click "Browse for an image file" to locate it manually. Once loaded, choose "Restore Image" to restore the full image, sit back, and wait for the process to complete, rebooting to the point in time where your chosen backup was taken.

You'll notice a "Browse Image" option – if your PC hasn't crashed and you simply want to restore an individual file from it, select this to mount the image as a virtual drive, accessible in File Explorer. Make sure you check "Enable access to restricted folders" to allow you to recover data from user folders and other protected places. Browse the contents for the file you want to restore and copy it back to your main hard drive.



Use System Restore as a fail-safe rollback system.

UNDO UNWANTED SYSTEM CHANGES

You've probably experienced the frustration of troubleshooting a problem that coincides with a recent installation or update, whether app, hardware, or Windows-related. Rather than waste time trying to track down a solution, why not roll your PC back to the moment before that problem started?

This is where System Restore comes in; it's Windows' own snapshot-based backup system that only records system changes, enabling you to roll things back without affecting any other files. It's not received much love in Win 10 – and may even have been disabled on smaller hard drives – but can still do a good job of undoing most system changes (with the exception of major feature updates).

You can verify it's switched on and roll back your PC from the same dialog box. Type "restore" in the Search box and click "Create a Restore point." Verify your system drive is switched on under "Protection Settings." You can also manually create Restore points here, although Windows should be smart enough to take a Restore point before major application and hardware changes; click "Create" to be doubly sure.

Should you need to roll things back, click the "System Restore" button. You're shown a recommended (the most recent) Restore point – click "Scan for affected programs" to see what changes will be reversed, followed by "Close" and "Next" to undo those changes. If necessary, select "Choose a different restore point" to go further back in time.

Step 2:

Back up key files

Next, it's time to tackle your personal files and folders – even if you've included them in your Macrium drive image. A file-based backup allows you to store multiple revisions of a file, giving you the option of reverting to an earlier version and providing insurance against unwanted file changes.

The obvious backup tool here is Windows' own File History – navigate to "Settings > Update & Security > Backup" to set it up. Click "Add a drive" and wait for all visible drives (including network drives) to be displayed. Once done, select your backup drive and review available options: frequency of backups, how long to keep them for, and what folders to include.

Going forward, File History should keep regular backups of files (including multiple versions). Restoring files (or earlier versions of a file) is done via File Explorer – navigate to the folder and click "History" under the "Home" tab of the ribbon. Now you can navigate the folder as a timeline, scrolling back to a specific date and time to click on a file to preview it. If it's the version you want, click the green button beneath the preview window to restore it to its original location, or click the settings button and select "Restore to" to create a copy of the restored file in another location.

File history alternatives

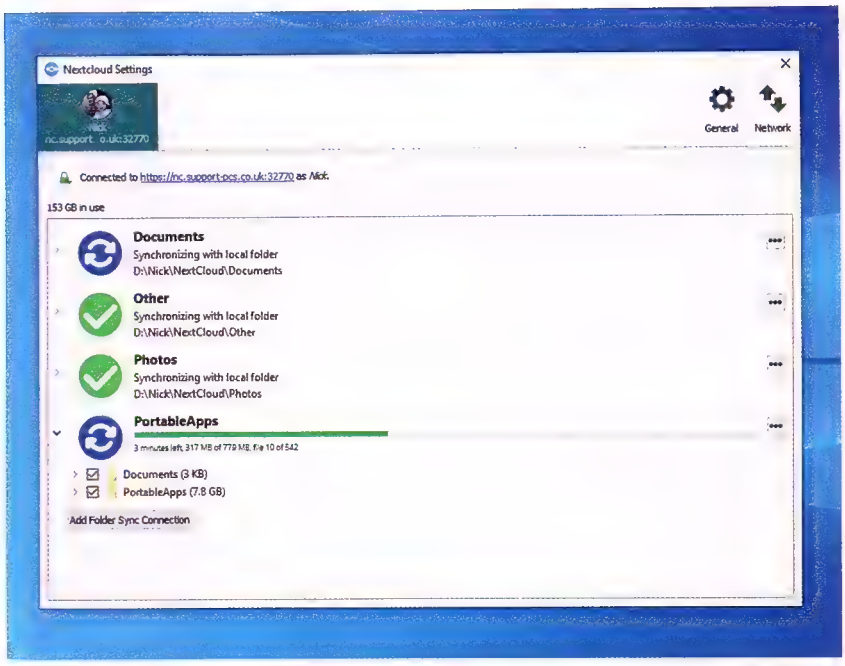
File History is not the most reliable backup tool and is quite slow and awkward. You're also restricted to just one backup location for your files, so regardless of whether you use it or not, you'll want a secondary backup stored elsewhere. If you've purchased the Home edition of Macrium Reflect, click "Create a File and Folder Backup" to back up selected folders following a similar setup wizard to image-based backups.

Another option is to make use of the cloud. OneDrive is already baked into Windows, but you only get 5GB of free storage unless you're a Microsoft 365 user (from $10 a month or $99 a year), in which case you get a much more generous 1TB of storage. Other cloud providers such as Dropbox or Google Drive offer similar plans.

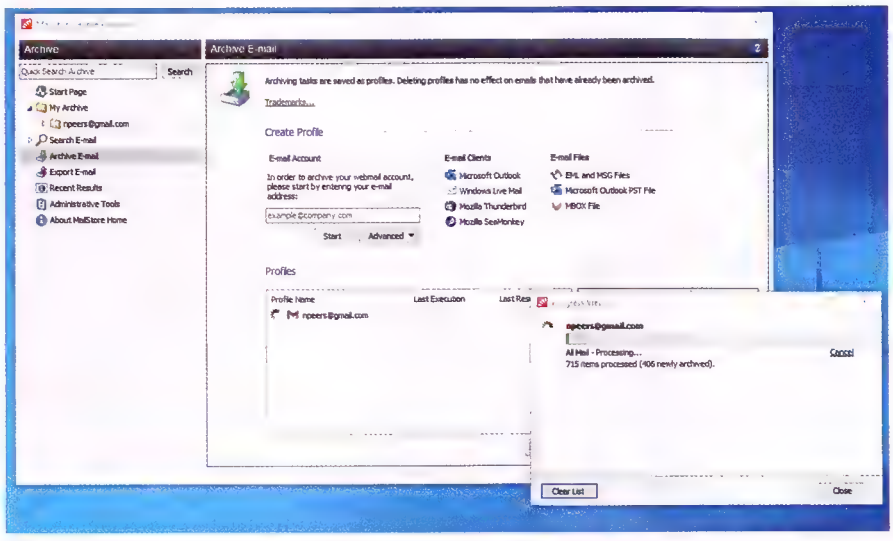
The upside of cloud storage is that your files are stored securely off-site, protecting them from fire, damage, or theft. There's a question mark, however, over the security of these files – encryption keys are typically held by the cloud storage provider, meaning they could technically hand those files over to a third party.

If you like the convenience of cloud storage – changes are uploaded in the background as they're made, and you have access to previous versions of files, just as with File History – but you don't trust the cloud, you have three basic options. The first is to deploy your own "cloud backup" solution, stored locally on your own network server. Our tool of choice is NextCloud (**www.nextcloud.com**) and in particular NextCloudPi (**https://ownyourbits.com/nextcloudpi/**), which can be set up as a Docker instance on a wide variety of hardware. If you need additional help setting NextCloud up, check out our tutorial in the November 2019 issue.

Once set up, you install the client on your PC and configure it to back up whichever folders you like to your network drive. You can also install the client on your phone or tablet for access to files from your cell. The downside is that your data isn't stored off-site, but continue reading for a way to get the best of all possible worlds…



NextCloud works in a similar way to OneDrive and Google Drive.



MailStore Home backs up your emails to a searchable archive.

MORE BACKUP OPTIONS

As things stand, you've protected your entire PC and your key files and folders. You've created multiple backups of each. But if you'd like to go further, the following apps and services are all worth considering.

First, want to back up your email? MailStore Home (**www.mailstore.com/en/products/mailstore-home/**) enables you to not just back up the email you download to your PC through Thunderbird or Outlook, but also works with any online POP3/IMAP account, as well as popular Internet mailboxes such as Gmail and Yahoo! You can easily download all or a portion of your mailboxes, and are also able to browse and search your archive offline, enabling you to free up space elsewhere.

We recommend installing it as a portable version, allowing you to keep everything in a single folder you can subsequently include in another backup – for extra peace of mind.

What about program settings? CloneApp (**www.builtbybel.com/ms-apps/cloneapp**) supports a wide range of popular programs and settings, and comes in two versions: one for regular desktop apps, the other handling apps you've installed from the Microsoft Store. Again, it's portable, so everything is easily backed up into one place. Use it to transfer settings to a new Windows installation or PC; for regular day-to-day backups, Macrium has all your app settings covered.

Step 3:
Secure cloud backups

How do you square the circle of off-site backups using your cloud provider without trusting it to keep your data safe? The answer is to use software on your PC that encrypts your data locally before uploading it to the cloud, using encryption keys only you have access to, thus putting your files beyond the reach of your cloud provider and any third party that might try to access them.

There are two basic approaches to encrypting cloud backups. If you want to save files directly to the cloud, you'll need Cryptomator (**https://cryptomator.org**), which can encrypt files on the fly using your own personal encryption keys. Use it to set up one or more encrypted "vaults," which are folders stored inside your cloud folder. Anything placed in here is encrypted before it's uploaded. It's

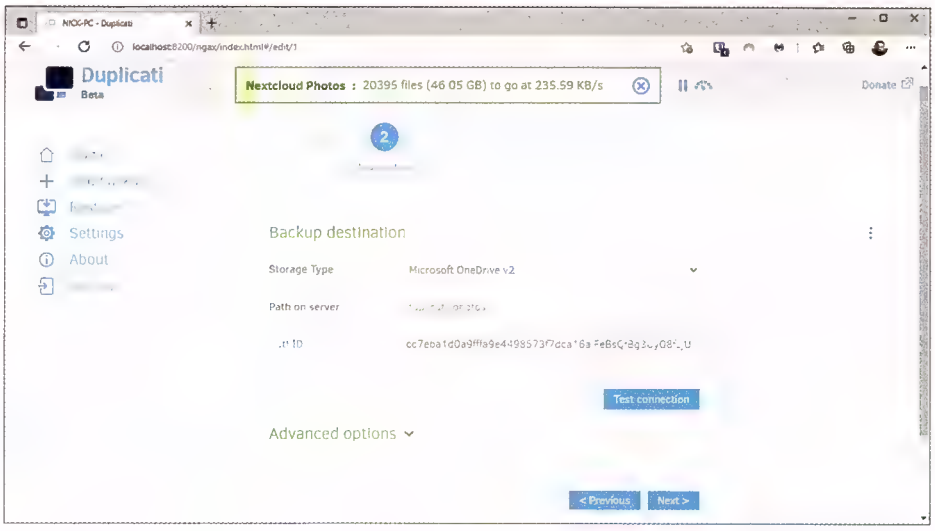
simple to use, there are (paid-for) mobile apps to access these files on the go, but it works best when used sparingly, perhaps with ultra-sensitive files rather than all your cloud-hosted files and folders.

Introducing Duplicati

Another approach is to use your cloud storage purely as an off-site backup location. The encryption process is the same: Your personal encryption keys scramble your backups before they are uploaded, in order to put them beyond the reach of your cloud provider. For this we recommend the free and open-source Duplicati (**www.duplicati.com**).

Duplicati is a block-based backup tool, splitting your data into small chunks that are AES-256 encrypted behind your choice of password, compressed, and then sent to your backup location: a proprietary cloud provider such as OneDrive or Dropbox, a local drive, or a server accessible through a range of popular protocols such as FTP or WebDAV. Duplicati supports file versioning, so once the initial backup is done, all changes are recorded incrementally to speed up file uploads and minimise the storage space used.

The program runs as a standalone tool, with access through both a graphical web interface and the command line for those who need it. You can install it directly in Windows, Linux, or macOS, or deploy it to a QNAP or Synology NAS via Docker.



Connect to your cloud account when setting up Duplicati.

Configure your backup

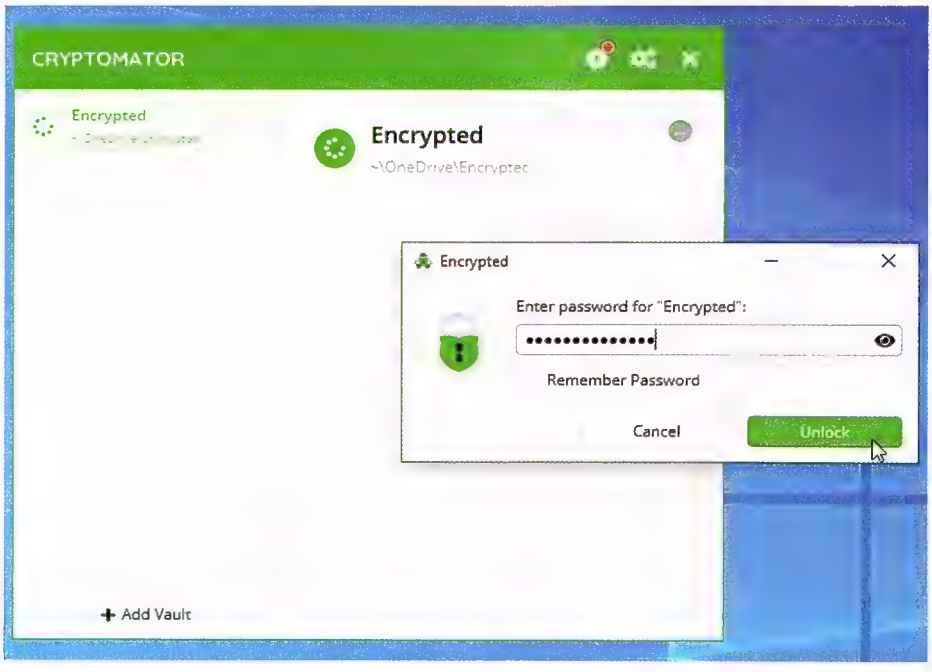
Once installed, Duplicati resides as an icon in your Notification area. Right-click this and choose "Open" or simply go to http://localhost:8200 in your browser to skip through the first-run wizard. If you install Duplicati on a shared PC, everyone has access, so you're first prompted to set up a password to restrict access to the program's web interface. Click "Yes" even if you're the only user, to review the program's main settings and tighten security where necessary.

It's worth remembering that backing up directly to the cloud is much slower than backing up to a local or network hard drive. Duplicati's default configuration will see it saturate your bandwidth attempting to upload as quickly as possible, so it needs reining in to prevent it from crippling your Internet connection while it's in use. Start by scrolling down to "Default options" and click "Pick an option" next to "Add advanced option." Select "Asynchronous-concurrent-upload-limit" under "Core Options" and set it to 1. When done, click "OK" and, if you set a password (which should be a strong one and stored in your password manager), you're prompted to log in with it.

Once you've configured Duplicati to your tastes, click "OK" to return to the main screen. Click "Add backup" to create your first backup job: Leave "Configure a new backup" selected and click "Next." Give your backup a suitably descriptive name and an optional description. Choose your level of encryption – the default AES-256 built-in option is best for most – then enter a strong password with the aid of a password manager. Click "Next."

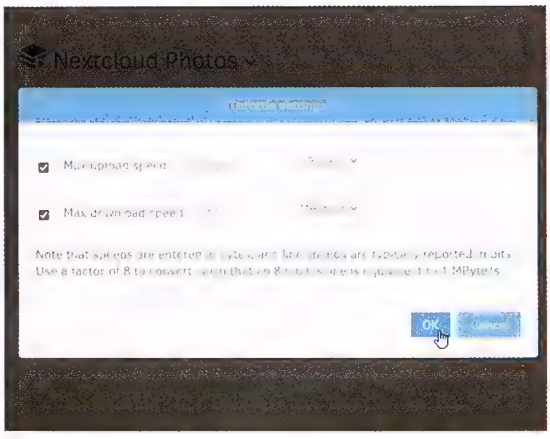
By default, your computer is chosen as the place to save your files – click the "Storage Type" drop-down menu to reveal all available remote options. After selecting your online storage, click the "AuthID" box to follow the prompts to link Duplicati to your chosen remote storage account. After the AuthID code has been generated and copied into the box, you need to manually enter the path on your server – for example, "/duplicati/" – and then click "Test connection," creating the folder when prompted.

Encrypt files before uploading them to the cloud.



Choose what to back up

Once created, click "Next" to use the file picker to select which



Set connection limits to prevent Duplicati overwhelming your Internet connection.

folder(s) to include in your backup. When it comes to selecting what to back up, you can exclude unnecessary files from folders using a combination of simple (Exclude) and complex (Filter) options. Exclude options include check boxes to ignore hidden, system, and temporary files, plus an option to ignore files over a user-specified size.

The Filters option is more complex – this is a combination of keywords or wildcards, with a choice of exclude or include filters, such as "Exclude directories whose names contain" or "Exclude regular expression." You can add as many filters as you need but be careful setting these – you may end up excluding files that you want to protect. Consult the Duplicati manual (**https://duplicati.readthedocs.io/en/latest/** – select "Articles > Filters") to find out how to apply them.

Next, choose your backup schedule – by default, backups are taken daily at 13.00, but you can edit this to your satisfaction, backing up as often as every few minutes if you so wish. Click "Next" again when done. Leave the "Remote volume size" alone, and then choose how long backups are kept using the "Backup retention" drop-down – if in doubt, choose "Smart backup retention." Finally, click "Save."

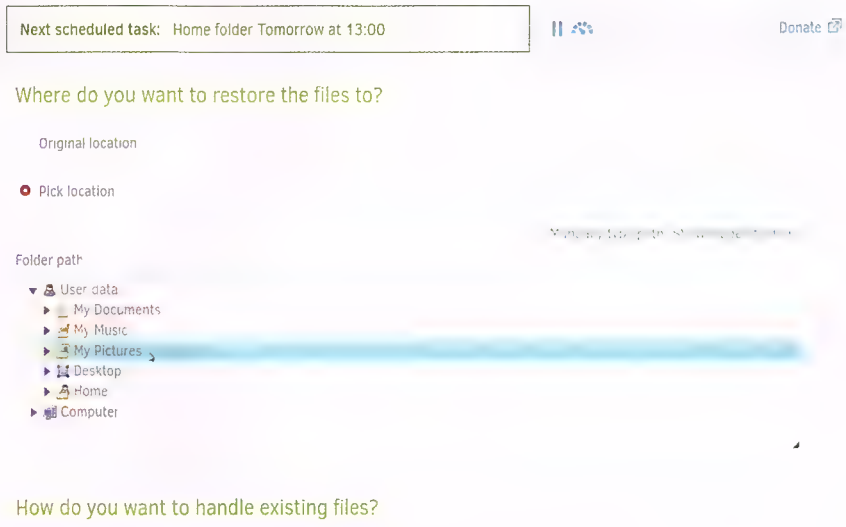
Set bandwidth limits

Your first backup job appears on screen, ready to start at the time you've set. You'll see a "Run now" shortcut next to it, but before clicking it you need to perform an additional step to prevent Duplicati from crippling your connection. Click the speedometer icon at the top of the screen to limit how much bandwidth Duplicati can use. We recommend capping your upload speed to 50 percent of your available bandwidth – for example, a 5Mbit/s connection is the equivalent of around 625KB/s, so cap the upload speed to 300KB/s. Also check the download limit box, even if you decide to leave it set to the default 10Mb/s.

Once done, click "Run Now" and leave Duplicati to its own devices – a progress bar appears indicating the current upload speed and how many files (and amount of data) remain to be transferred. If your Internet connection feels sluggish, return to the speedometer to set a lower upload limit. Depending on the size of the folder(s) you're backing up, the initial process could take days if not weeks to complete, so if you've not already done so, take a local backup, too – either with Duplicati or another app – as a form of insurance.

You can add as many backup jobs as you need (although you should stagger them so they don't attempt to all run at once) – edit an existing backup job by clicking the down arrow next to its name to reveal a list of clickable options. Choose "Edit" under "Configuration" to access the same wizard you used to set up the backup, and make whatever changes you need.

We also recommend backing up your Duplicati configuration files – in case your computer dies, and you need to restore your files to another PC. Expand each backup job's settings and click "Export" under "Configuration." Leave "To File" and "Export passwords" selected, check "Encrypt file" (and supply a password) to protect it, then click "Export." Store the file somewhere safe. Should the day come when you need to restore your data – whether a specific version of a file or everything after a catastrophic crash – check out the box below. ■



You can restore files to another location with Duplicati.

RESTORE YOUR DUPLICATI BACKUPS

How do you restore data from Duplicati backups? If you've not had to reinstall Windows from scratch, simply open Duplicati in your browser, expand the relevant backup job, and click "Restore files" under "Operations." If you've had to reinstall Duplicati from scratch on a new computer or install, and you backed up your configuration files, choose "Restore from configuration," click "Next" to select your configuration file, and enter your password. On clicking "Next," the backup job should be restored, and you can start the restoration process from there. If you didn't back up the configuration file, choose "Restore > Direct restore from backup files" and click "Next." This is a similar process to setting up your backup: Choose your provider, enter the destination path, and link to the account. You then input the password you used to encrypt the backup, and that unlocks its contents for restoration.

Whichever option you choose, use the file picker to choose which folders to restore (select the top-level folder to select everything in your backup). You can search for specific files and folders by keyword, too. If you're looking to roll back to an earlier version of a file, use the "Restore from" menu.

Click "Continue." You can restore to the original location or select a folder path to restore to. By default, existing files are overwritten, but you can save a copy with a timestamp in the specified location. Look out for the "Restore read/write permissions" box – ordinarily you'll want to preserve these, so check this before clicking "Restore" and waiting for the files to copy back to your PC.

System news

Intel, the sleeping giant is finally stirring. Mark Williams explains why AMD should be concerned.

MARK WILLIAMS
Mark is an IT professional with a strong interest in voiding warranties.

AMD's success in the CPU market was always going to have its honeymoon period. AMD caught Intel napping on the process and technology front. It was always only going to be a matter of time before the sleeping dragon woke and began to reclaim its crown.

Since the appointment of the former star employee, Pat Gelsinger, as CEO of Intel, big structural changes have been made to the company and its direction. At the recent Intel Accelerated event, Intel laid out the future for its chip manufacturing future, unveiling an aggressive and ambitious roadmap with new process nodes coming online every year, building up to reclaim the industry lead in 2025.

One of the major things Intel wanted to do with this step change was to clear up its confusing and obsolete process node naming scheme, weaning itself off the outgoing mature 14nm node and now producing most wafers on its 10nm SuperFin process, which most agree is equivalent to TSMC's 7nm. With TSMC moving to 5nm and 3nm soon thereafter, Intel's naming scheme is mismatched against the rest of the industry despite being equally as performant.

To re-align itself, Intel is renaming its upcoming 10nm Enhanced SuperFin node, which is to appear later this year in its 12th Gen "Alder Lake" products, to simply Intel 7 (no nm suffix), bringing with it a 10-15 percent performance/watt increase over 10nm SuperFin.

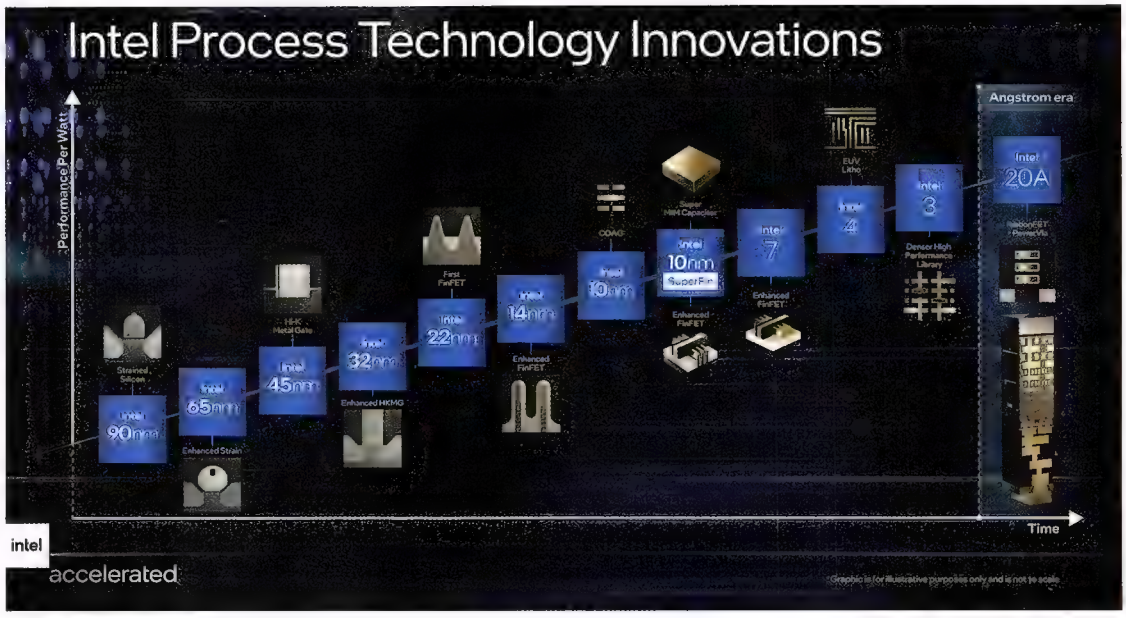
Intel 4 comes next (previously 7nm on old roadmaps), this will be seen in Meteor Lake products and will bring a substantial 20 percent performance/watt increase and will see Intel finally shift to using extreme ultraviolet (EUV) lithography. Intel 3 follows that (formerly 7nm+), which will be more of a refinement of Intel 4 using higher performance and more dense libraries.

With many wondering what happens when we run out of nanometre designations, Intel has decided the next size designation is the Ångström (Å). An Ångström is a unit of measurement where 10Å equals 1 nanometre.

Oddly these measurement types have almost no correlation to any feature size of transistors made with a particular node. That stopped being the case decades ago, just think of these number designations simply as a node name rather than an exact feature size.

Succeeding Intel 3 is Intel 20A in 2024, which will usher in a new transistor that Intel has been developing called gate-all-around; or as Intel prefers, RibbonFET. Think of it like FinFETs but turned on its side and stacking multiple fins/wires above each other like ribbons. This will be the first major change in transistor technology since FinFETs were introduced in 2010. Intel 20A will also introduce PowerVias. A backside power delivery method that splits power delivery out from the usual top side, where it must share space with data lines at each layer, making for a headache managing data signal integrity. Now it's handled at the rear of the package, making for a much cleaner, layered approach where power is all on one side, transistors in the middle and the sensitive data lines on the other side, cleaning up signal pathways.

Finally, in 2025 Intel 18A will come into play using second generation EUV "High NA" equipment from ASML (the leader in lithography machinery for silicon foundries). Intel claims it has an agreement with ASML to be the first exclusive customer for this equipment – leaving TSMC out in the cold. Using Intel 18A with this new equipment, Intel says it will reclaim the market technology lead. Leaving architectures aside, process node improvements are just as important to processor performance enhancement, and seeing Intel get very aggressive on this front is exciting news that will spice up the ongoing core wars for years to come. The question now becomes whether TSMC can match it for AMD's sake? ■



Intel's new roadmap covers several important evolutions, leading to 2025 when it hopes to reclaim the CPU crown from AMD.

Market snapshot

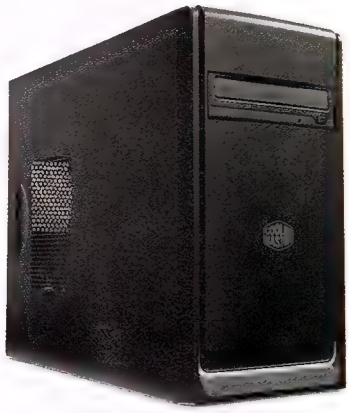
A sampling of PC systems available this month.

$1,299 – tinyurl.com/APC498MWV

MWAVE OFFICE PRO I7 WORKSTATION

If you demand a bit more performance from your office computers and need an upgrade, this is an enthusiast-level system that won't break the bank. Sporting an 8-core processor, it'll have more grunt than most other office computers, and with the included 2.5Gb LAN port and W-Fi 6 (AX) support it'll let you quickly transfer those large files you need to process. The RAM is interesting; rated higher than what the 10700 officially supports, it'll facilitate 11th Gen drop-in processor upgrades down the track. The NR200 case being a DIY friendly chassis offers easy access to the internals and is very roomy for its size. If you foresee a need for upgrades down the track, this is a good system to consider. Just be mindful that the PSU will need an upgrade if installing a graphics card.

CPU: Intel Core i7 10700 **Cooler:** OEM **Motherboard:** MSI H510i Pro WIFI **Graphics:** Integrated **Memory:** HyperX 16GB DDR4 3200MHz **Storage:** Crucial P2 500GB M.2 NVMe SSD **Power Supply:** Silverstone SX450-B 450W **Case:** Cooler Master NR200.



$979 – tinyurl.com/APC498SCO

SCORPTEC HORNET CORE i5 OFFICE PC

Looking for something cheap and snappy to handle basic office tasks? This could be all you need. With multiple video-out ports, Wi-Fi, and a standard complement of USB ports, this system will plug into just about any work situation. The i5-10500 has a 200MHz speed bump over the more common 10400 processor, which will keep you skipping through general tasks with ease. The included memory is standard fare with, importantly, a comfortable 16GB of it. The 500GB SSD should suit most users and being M.2 will be zippy when launching programs. The power supply is probably the weakest part in the system, being included with the case – these tend to be of questionable quality at times. Apart from that this is a handy system any office will be happy to have around.

CPU: Intel Core i5 10500 **Cooler:** OEM **Motherboard:** MSI PRO-VDH WiFi B460M Graphics: Integrated **Memory:** HyperX Fury 16GB 2666MHz DDR4 **Storage:** Western Digital WD Blue SN550 500GB M.2 SSD **Power Supply:** Cooler Master 420W **Case:** Cooler Master MasterBox E300L.

$5,239 – tinyurl.com/APC498-JWC

JW COMPUTERS RAZAR 3080

Do you mean business when you play games? This system certainly does. Aside from looking great on any desk it has the chops to back it up. With one of the fastest gaming CPUs from AMD and a cooler to keep boost clocks high all day long, you won't be left wanting for much. The RTX 3080 is a beastly card that although not at the top tier of GPUs, it'll likely be fine for anyone not running a 4K monitor. High refresh rate ultra-wide monitors? No problem. The premium RAM is nice to see and is a great match for the CPU to eke out the most it has to offer. The sizeable and fast SSD is great for large game libraries. The feature-rich motherboard and impressive PSU are also solid choices. A fantastic rig for any diehard gamer.

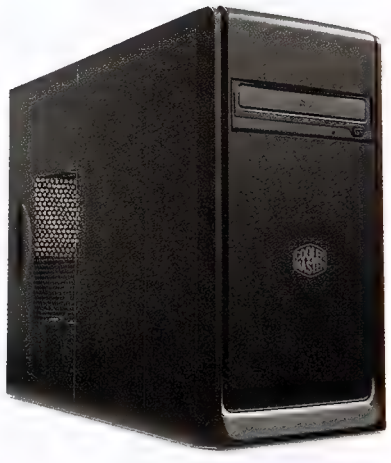
CPU: AMD Ryzen 7 5800X **Cooler:** Cooler Master MasterLiquid ML360R ARGB **Motherboard:** Asus ROG Strix X570-F **Graphics:** Asus Strix RTX3080 Gaming O10G 10GB **Memory:** G.Skill Trident Z 32GB DDR4 3600 RGB **Storage:** 1TB M.2 NVME GEN4 SSD **Power Supply:** Asus ROG Strix 850W **Case:** Lian Li PC-O11 Dynamic Razer.

$7,638 – tinyurl.com/APC498PLE

PLE COMPUTERS KINETIC

Don't let the diminutive 25-litre size of this system deceive you, it'll pump out more FPS than most other full-sized systems. Crammed inside are premium gaming parts like an AMD 5800X and a top tier RTX 3080 Ti – big hitters that generate big temperatures. This is where PLE's custom water cooling comes in. In this form factor cooling is always a concern and water is a nice way to deal with that. The custom water loop comes at a premium though, adding at least $1,400 to the price. It does look fantastic though and will never overheat. 32GB of RAM, 1TB SSD, and 1,000W PSU all make for a system that'll last a long time at the top of the spec charts. A little beast for the discerning gamer.

CPU: AMD Ryzen 7 5800X **Cooler:** PLE Custom Watercooling CPU + 1 GPU **Motherboard:** Asus ROG Strix X570-I Gaming **Graphics:** Zotac Gaming GeForce RTX 3080 Ti AMP Holo 12GB **Memory:** Corsair 32GB DDR4 Vengeance RGB Pro SL C16 3200MHz **Storage:** Samsung 980 Pro Series Gen4 1TB M.2 NVMe SSD **Power Supply:** SilverStone SX1000 SFX-L **Case:** Jonsplus i100 Pro Black. ■



BLUEPRINTS

VALUE- AND PERFORMANCE-DRIVEN HYPOTHETICAL BUILDS

PC BUILDER

Budget

We'd like to say it's time to upgrade our AMD budget build's processor.

Stock availability is still hamstringing our upgrade efforts. Since we don't need the integrated graphics offered by the Athlon 3000G, we contemplated switching up to a Ryzen 3 3100, doubling our core and thread counts. But this chip is still largely out of stock, and with no 5000-series budget Ryzen 3 CPU on the horizon, we're left with the dual-core 3000G. It's a bit cheaper this month, at least.

The AMD machine does get a few fun new additions, though. We've got a new motherboard, the MSI Pro B450M Pro-M2 (we don't know why it has "Pro" in the name twice either), and a new SSD, the SX8200 Pro NVMe drive from Adata. It promises upward of 3000MB/s read speeds in a PCIe 3.0 system, and comes at an excellent price for a quarter-terabyte of M.2 storage.

Our Intel build saw prices increasing slightly in some areas, with the Core i3-10100 now going for around $189 (up from $130) and the Gigabyte B460M mobo rose by $10, too. Both GPUs we recommend for the two budget systems have seen mild drops in street price, no doubt aided by crackdowns on cryptocurrency farming, but they're still far above what you should pay. Second-hand GPUs are still flooding sites like eBay, but be careful; cards that have previously been used for crypto mining may suffer from reduced longevity.

The Intel build gets two new components: memory and SSD. The memory is a swap back to Team Group's Vulcan Z RAM at 3,000MHz, a reliable and affordable 2x 8GB kit that we can always recommend to builders on a budget. The SSD is a slightly more interesting tale...

Last issue, we opted for XPG's Gammix S5 M.2 drive, a supposedly gaming-oriented SSD with 256GB of storage. This was a mistake; the Gammix S11 is superior, offering 3D NAND flash memory rather than the S5's older, slower 3D TLC components. Despite only a slight price difference, the S11 has hugely faster read times, with a maximum read speed of 3.5GB/s in a fully compatible system.

AMD INGREDIENTS

PART		PRICE
CASE	Corsair 4000D Airflow	$120
PSU	500W EVGA BR 80+ Bronze	$90
M/BOARD	MSI Pro B450 Pro-M2 MAX NEW	$90
CPU	AMD Athlon 3000G	$139
GPU	AMD Radeon RX 6700 XT 12GB	$1,100
RAM	16GB (2x 8GB) GelL Orion @ 3,000MHz	$140
SSD	256GB Adata SX8200 Pro M.2 NVMe NEW	$70
HDD	1TB WD Blue 1TB 7200	$60
OS	Windows 10 Home 64-bit OEM	$60
PRICE		$1,869

INTEL INGREDIENTS

PART		PRICE
CASE	Corsair 4000D Airflow	$120
PSU	500W EVGA BR 80+ Bronze	$90
M/BOARD	Gigabyte B460M DS3H V2	$120
CPU	Intel Core i3-10100	$189
GPU	Nvidia GeForce RTX 3060 12GB	$950
RAM	16GB (2x 8GB) Team T-Force Vulcan Z @ 3,000MHz NEW	$130
SSD	256GB XPG Gammix S11 M.2 PCIe 3.0 SSD NEW	$93
HDD	1TB WD Blue 1TB 7200	$60
OS	Windows 10 Home 64-bit OEM	$60
PRICE		$1,812

PC BUILDER

Mid-range

There was precious little to change in our mid-range PCs.

"The most significant alteration is the AMD system's new motherboard, an X570-Plus motherboard from Asus's TUF Gaming range. With an M.2 heat shield, PCIe 4.0 support, and a slick black-and-yellow color scheme, it's a solid choice of board for a mid-range custom PC, capable of supporting 3000- or 5000-series Ryzen processors."

We've made some small shuffles here and there based on current pricings. Most of these components remain the best-value parts of their kind (the Enermax and Cooler Master AIOs in particular), but we were able to make a few changes. The most significant alteration is the AMD system's new motherboard, an X570-Plus motherboard from Asus's TUF Gaming range. With an M.2 heat shield, PCIe 4.0 support, and a slick black-and-yellow color scheme, it's a solid choice of board for a mid-range custom PC, capable of supporting 3000- or 5000-series Ryzen processors. Note that a BIOS update may be required for 5000-series chips; this is especially likely if you're buying your motherboard second-hand.

The AMD system also gets new memory, another lateral shift to G. Skill's dependable Ripjaws V RAM. As usual, the change is to keep abreast of memory pricing, which is constantly moving. When picking memory, work out the speed and capacity you want, then narrow it down to the best-value kit from trusted named brands.

Our mid-range Intel build gets a slightly updated PSU, the EVGA SuperNOVA 650 G5. You can look out for EVGA's G6 series now, but the G5 models are still great PSUs and currently more affordable. The Intel rig also returns to Corsair's excellent Force MP600 PCIe 4.0 SSD, thanks to a sale that brought the price down.

With CPUs still in high demand (as we were writing this, an article popped up about a smuggler arrested in Hong Kong for attempting to conceal 256 Intel chips on his legs), we considered swapping out the Core i7-11700K for its 11700F counterpart, which is currently more readily available and about 80 dollars cheaper. We ended up leaving the 11700K in place, due to its slightly better performance and overclocking capabilities. The 11700F lacks integrated graphics and has its multipliers locked against manual overclocking, but if those aren't issues for you, we still recommend it.

AMD INGREDIENTS

PART		PRICE
CASE	Lian Li PC-O11-Dynamic	$200
PSU	650W Fractal Design Ion Gold	$140
M/BOARD	Asus AM4 TUF Gaming X570-Plus NEW	$270
CPU	AMD Ryzen 5 5600X	$400
COOLER	240mm Cooler Master Masterliquid ML240L RGB	$100
GPU	Nvidia GeForce RTX 3070 8GB	$1,600
RAM	16GB (2x 8GB) G.Skill Ripjaws V Series @ 3,600MHz NEW	$150
SSD	500GB PNY XLR8 CS3040 M.2 PCIe 4.0 NEW	$140
HDD	1TB WD Blue 1TB 7200	$60
OS	Windows 10 Home 64-bit OEM	$60
PRICE		$3,120

INTEL INGREDIENTS

PART		PRICE
CASE	Lian Li PC-O11-Dynamic	$200
PSU	650W EVGA SuperNOVA 650 G5 NEW	$130
M/BOARD	ASRock Z590M PRO4	$200
CPU	Intel Core i7-11700K	$520
COOLER	Enermax Liqmax III 240 RGB	$90
GPU	AMD Radeon RX 6800 XT 16GB	$1,700
RAM	16GB (2x 8GB) G.Skill Ripjaws V Series @ 3,600MHz NEW	$150
SSD	500GB Corsair Force MP600 M.2 PCIe 4.0 NEW	$130
HDD	1TB WD Blue 1TB 7200	$60
OS	Windows 10 Home 64-bit OEM	$60
PRICE		$3,240

PC BUILDER

Turbo

GPU prices keep falling, even if they're still a far cry from their RRPs.

We still don't recommend paying through the nose for one of the high-end cards right now, but at least street prices aren't sitting above double the original value. If you really want a new GPU, your best bet is to track restocks via social media updates and camp out reseller websites. High-end CPU prices are stable(ish) at the time of writing, but expect delays if ordering online.

While we're sticking with the same chips, both our turbo builds boast shiny new motherboards. The AMD build gets the MSI MPG X570 Gaming Plus Wi-Fi, while the Intel machine gets the Asrock Z590 Steel Legend Wi-Fi. Both have PCIe 4.0 capabilities and Wi-Fi support, and we love the clean silver aesthetic of the Steel Legend.

Both machines get new SSDs, too, as the new generation of ultrafast 3D NAND drives make the previous round of PCIe 4.0 SSDs look slow as heck. The AMD system has a Samsung 980 Pro, while the Intel build gets Gigabyte's shiny new Aorus 7000s drive. Both are 1TB drives, offering maximum read speeds of a staggering 7,000MB/s and write speeds of up to 5,000MB/s (5,500 in the case of the Gigabyte drive). These SSDs are a bit more expensive than their regular PCIe 4.0 counterparts, but their performance is nigh-unparalleled – without shelling out for an insane new Optane SSD.

A new power supply also felt appropriate for the AMD machine, given some pricing shifts, and we opted for Nzxt's excellent C750 model, with 80+ Gold efficiency certification. We like Nzxt's PSUs; they're clean little units in matte black, and the C750's modular design means we won't have any excess cables to worry about.

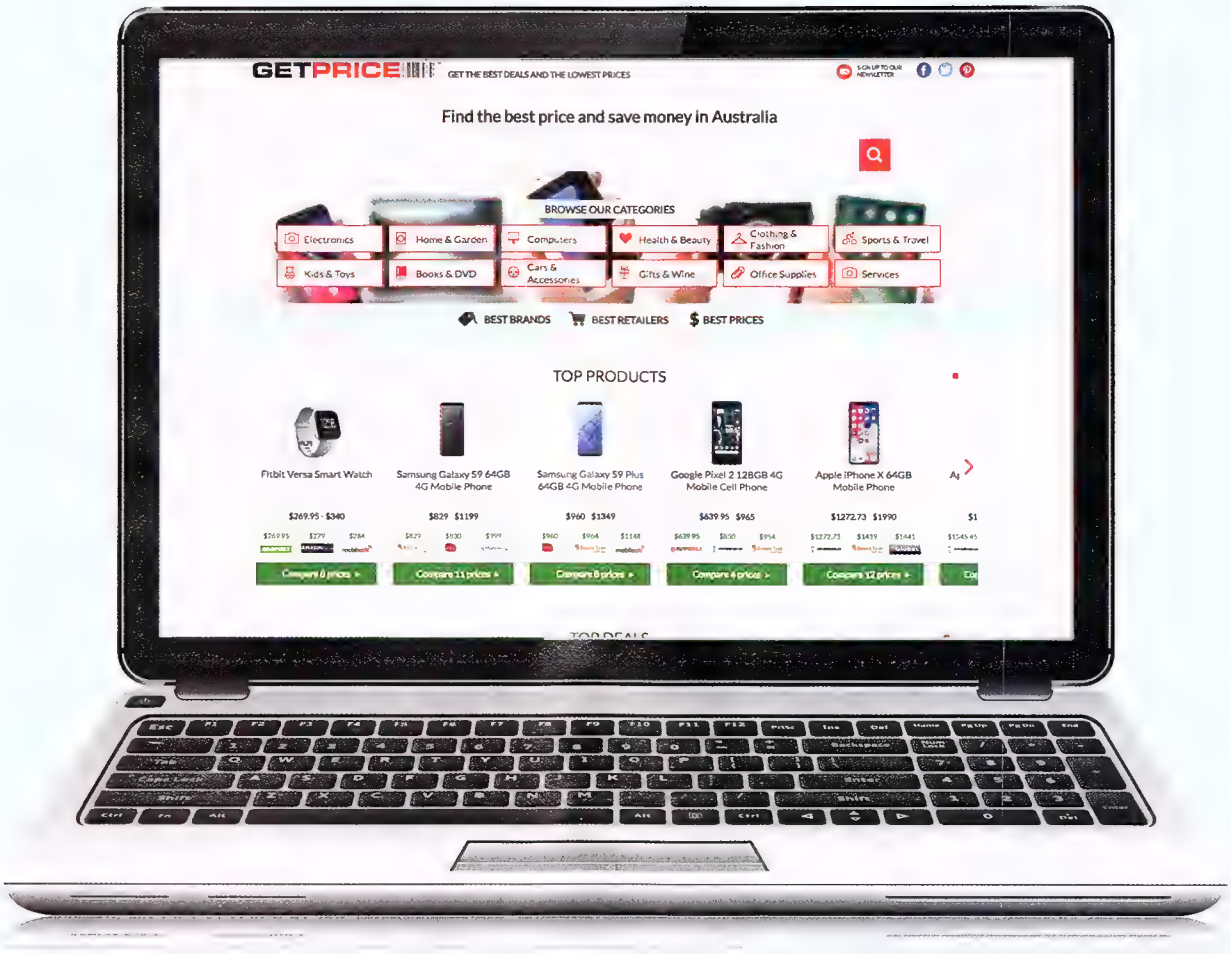
Finally, we sprung for a new AIO. Yes, there might be more affordable ones, but we couldn't resist Lian Li's awesome Galahad 360 cooler. The sleek white model is a high-end AIO with flashy RGB lighting and machined aluminum components, such as additional heat shielding on the radiator. The pump block head with the Lian Li logo is magnetic, and can be rotated or replaced with a simpler aluminum plate that accentuates the lighting around the edges. ■

AMD INGREDIENTS

PART		PRICE
CASE	Phanteks Enthoo Pro 2 Tempered Glass	$220
PSU	750W NZXT C750 80+ Gold **NEW**	$140
M/BOARD	MSI MPG X570 Gaming Plus Wi-Fi **NEW**	$245
CPU	AMD Ryzen 7 5800X	$620
COOLER	Lian Li Galahad RGB AIO 360mm White **NEW**	$259
GPU	Nvidia GeForce RTX 3080 10GB	$2,300
RAM	32GB (2x 16GB) Patriot Viper Steel DDR4 @ 3,600MHz	$280
SSD	1TB Samsung 980 Pro M.2 PCIe 4.0 **NEW**	$270
HDD	6TB Western Digital Blue	$240
OS	Windows 10 Home 64-bit OEM	$60
PRICE		$4,634

INTEL INGREDIENTS

PART		PRICE
CASE	Phanteks Enthoo Pro 2 Tempered Glass	$220
PSU	750W EVGA SuperNOVA 750 G5	$180
M/BOARD	ASRock Z590 Steel Legend Wi-Fi **NEW**	$260
CPU	Intel Core i9-11900K	$820
COOLER	MSI MAG CoreLiquid 360R AIO	$150
GPU	AMD Radeon RX 6900 XT 16GB	$2,100
RAM	32GB (2x 16GB) G.Skill TridentZ RGB @ 3,600MHz	$340
SSD	1TB Gigabyte Aorus Gen4 7000s M.2 PCIe 4.0 **NEW**	$300
HDD	6TB Western Digital Blue	$240
OS	Windows 10 Home 64-bit OEM	$60
PRICE		$4,670



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PC BUILDER MASTERCLASS

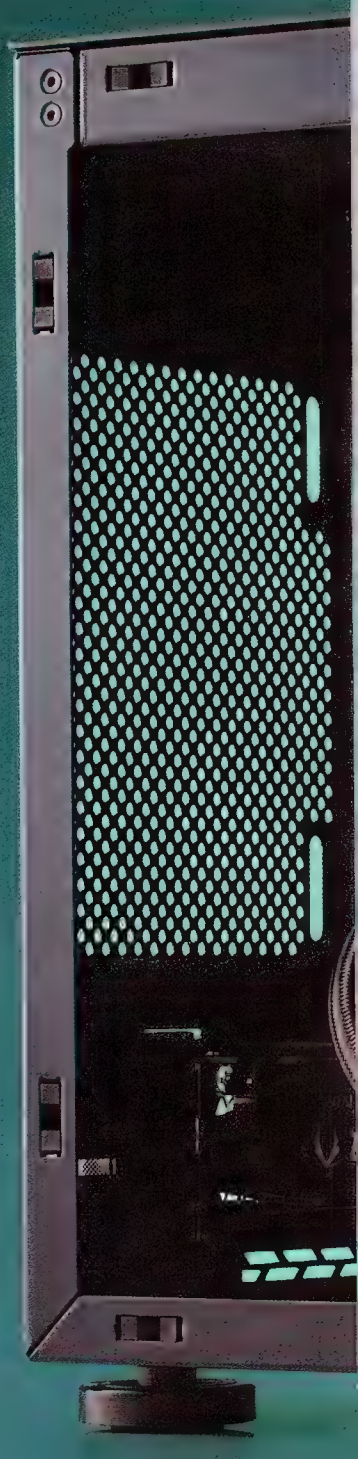
The Mini Maestro PC

When it's not about gaming, what can you get on a budget?

Small form factors are one of our favorite things in the mysterious depths of the tech industry. Year after year, hardware is condensing and we're getting more punch from smaller devices. Yes, we all dream of having a monster machine as part of our setup, capable of rinsing everything we throw in its direction and giving NASA a run for its money. However, there is something intriguing about Mini-ITX builds that we just can't escape from.

Having a smaller rig can give you a cleaner setup and more room (obviously), and they look pretty neat, too, in our professional opinion. It seems as though Mini-ITX systems are nothing but positive news, but that isn't necessarily the case. GPUs such as the impossible-to-grab 3090 cards, for instance, are generally too big for these chassis, so we probably have some waiting to do before we can get cards that powerful in this format. Along with size restrictions on the GPU, there is the overall awkwardness of putting one of these rigs together. It goes without saying that PC building can be a tricky business that makes you want to scream out loud when things go awry. So, if that's a regular occurrence in a normal ATX build, putting together a mini system is never likely to be a bundle of laughs.

We decided to rise to the challenge and build a machine that is more than capable of decent gaming performance and reasonably affordable, all bundled up in a compact ITX case. So, turn the page to see what develops out of our love of small form factors. SAM LEWIS



MINI MAESTRO PC INGREDIENTS

PART		STREET PRICE
CPU	Intel Core i5-10600K	$320
GPU	Zotac GeForce RTX 3060 Ti 8GB Twin Edge OC	$1,100
RAM	16GB (2x 8GB) Crucial Ballistix DDR4-3600	$160
M/BOARD	Asus ROG STRIX Z490-I Gaming Mini-ITX	$300
OS STORAGE	1TB Samsung 980 Pro M.2 PCIe 4.0 SSD	$300
PSU	Be Quiet! SFX L Power PSU 500W	$140
COOLER	Be Quiet! Pure Loop 120mm AIO	$110
CASE	Lian Li TU150	$130
TOTAL	Be Quiet! Pure Loop 120mm AIO	$2,561

LIAN LI

MOTHERBOARD

ASUS ROG STRIX Z490-I GAMING MINI-ITX

$300 | www.asus.com

Although not recommended for the latest-generation Intel CPUs, this last-gen Z490-I will be more than good enough for our build with a little BIOS update. Yes, this is tedious, and if you can get your hands on a newer Z590-I board, go for it, but with a little patience, it's worth the effort. With Intel Wi-Fi 6 AX201 connectivity, support for up to 64GB DDR4 memory across two slots, and two M.2 slots, both supporting SATA and PCIe 3.0 x4, it's still pretty future-proof. Looking this sleek, too, it's a good choice.

"With Intel Wi-Fi 6 AX201 connectivity, support for up to 64GB DDR4 memory across two slots, and two M.2 slots, both supporting SATA and PCIe 3.0 x4, it's still pretty future-proof."

CPU

INTEL CORE I5-10600K

$320 | www.amazon.com.au

One of the main problems with chips right now is the lack of availability, but thankfully they aren't as sought-after as the latest GPUs, and this i5-10600K is in stock at the time of writing. It was a significant CPU from Intel on release as it addressed a key issue at the time: the lack of Hyper-Threading. It introduced 12 threads, for better multithreaded performance in productivity-based tasks like rendering and a more stable experience for gaming. Costing just $230, it offers good performance at an affordable level. In terms of numbers, it has six cores, 12 threads, and a 14nm architecture, which is still a nice sweet spot and is more than good enough for a processor with this price tag. It also packs a 4.9GHz max turbo frequency. Where it suffers a bit is future-proofing, as it doesn't support PCIe 4.0.

POWER SUPPLY

BE QUIET! SFX L POWER PSU 500W

$140 | www.bequiet.com

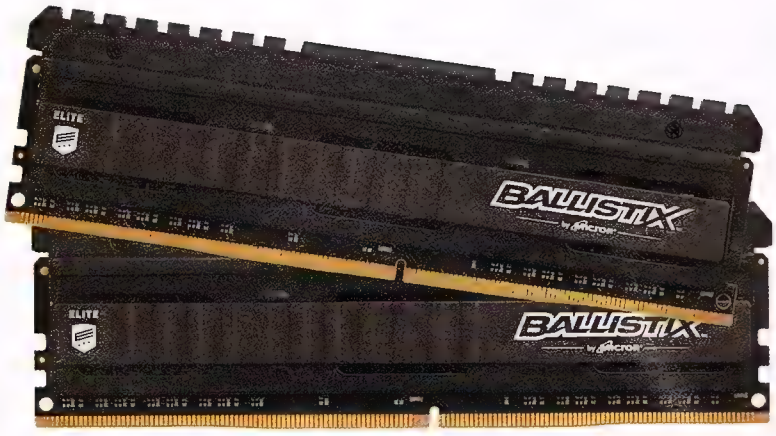
We've gone with Be Quiet! for our PSU. Its 80+ gold certification with up to 92 percent efficiency has reeled us in. The SFX form factor is recommended for ITX builds, so it's a welcome addition to our rig. With four PCIe connectors, you can hook some decent GPUs up, too. Pairing it with our Be Quiet! cooler should provide quiet overall performance due to their low-noise optimisation.

GRAPHICS CARD

ZOTAC GEFORCE RTX 3060 TI 8GB TWIN EDGE OC

$1,100 | www.zotac.com

We all know Mini-ITX cases are tight on space, so a 3060 Ti is a great fit for our build. This card is a nippy little GPU that offers 1440p AAA gaming with ray tracing. Nvidia claims that it beats the previous superior RTX 2080 Super. That card had a $700 RRP, so this time you're getting more bang for your buck. Nvidia's second-gen RTX technology is introduced by the GPU's Ampere architecture, so you get traditional 3D rasterisation combined with ray-traced elements. Just don't pay the current street price.

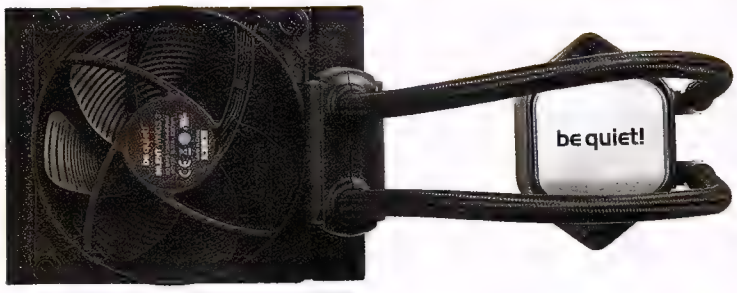


MEMORY

16GB (2X 8GB) CRUCIAL BALLISTIX DDR4-3600

$160 | www.crucial.com

Choosing RAM can be tricky. Other than the fact that there is an abundance of sticks on the market, there are lots of potential configurations when it comes to CAS timings and memory speeds. We have gone down a budget route to keep costs low by choosing Crucial's Ballistix 16GB DDR4-3600 sticks. It's a solid kit that will be more than good enough for our build, but if you want 32GB, it'll cost $300. If you're a Chrome tab hoarder and hate closing down programs, that's probably a good choice.



CPU COOLER

BE QUIET! PURE LOOP 120MM AIO

$110 | www.bequiet.com

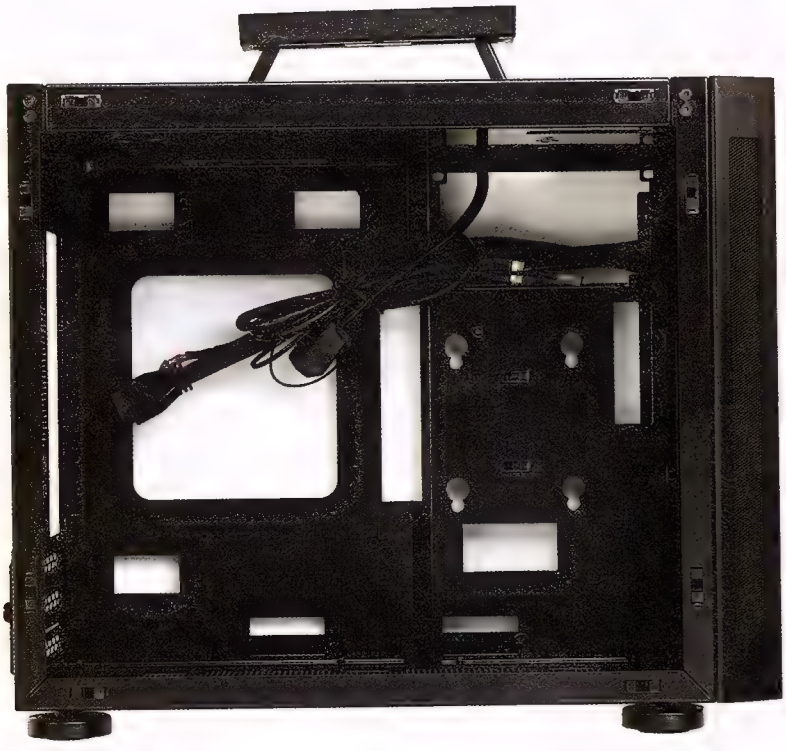
The clue's in the name, right? As well as being physically compact, we want the sound to be small in size, too. The appropriately named Be Quiet! Pure Loop 120mm AIO will hopefully provide a subtle cooling experience for our CPU. With an all-black design and muted white LED illumination, this is a sleek-looking cooler. The Pure Wings 2 120mm fan operates very quietly, and paired with the Pure Loop aluminum radiator, this is an excellent cooler for compact builds.

STORAGE

1TB SAMSUNG 980 PRO M.2 PCIE 4.0 SSD

$300 | www.samsung.com

You could say we've gone a little overkill on our SSD, and you'd be right if we'd picked the 2TB variant! Jokes aside, this 1TB model is a beast of an SSD, featuring a very speedy PCIe 4.0 interface, with backward compatibility for PCIe 3.0. it'll deliver great performance across all sorts of tasks, and boasts upward of one million random read/write IOPS and peak sequential read/write speeds of around 7GB/s and 5GB/s respectively. With a PCIe 4.0 CPU and motherboard it would make more sense, but regardless, this SSD will be great in our mini build, and perfect for the future.



CASE

LIAN LI TU150 MINI-ITX

$130 | www.lian-li.com

Who thought a mini form factor case could look so mean, utilitarian, and solid? This thing looks like it could survive a nuclear war. And scrap your laptop, because this desktop has a handle on top for portability, too. The Lian Li case is a well-put-together chassis for our rig, with decent airflow all around. Our windowless version even has more vents toward the bottom of the side panels, just about where our GPU will sit – perfect. With the PSU mount near the top, there's also a side vent to keep things ice cold.

Length of time 1-2 Hours Level Of Difficulty Medium

Building the Mini Maestro

A mean mini fighting machine.

02 Bare bones

Stripping down the case is one of the best things to do at the start of a build. When all the panels are off, it helps you see what you are working with and gives you as much room as possible – a must for cramped ITX systems. Plus, it's a good chance to see the case without all the hectic mess that's about to unfold. Without any glass panels, this chassis looks pretty intimidating, considering its size. Right, let's get into this mini beast. First, pull off the side panels using the concealed push pins. Easy-peasy. The same goes for the top panel. To get the front panel off, remove the plastic clasp pins that secure it before popping it off with the push pins again. Once that's done, we can take out the dust filter and – boom – there's a meaty-looking skeleton (oh, the irony).

02 In goes the CPU

As with all Intel CPUs, it's vital that you don't touch the bottom pins. These are super-delicate, so just gently pinch the sides of the chip when placing it on the motherboard. Lift up and raise the retention arm. To do so, you have to push it outward to unhook it, then lift the arm up to reveal the socket, leaving the plastic cover in place. Next, we need to match up the arrow on our Intel chip with the arrow on the motherboard. Once it is positioned correctly, we can lower the bracket back. Pull the retention arm down slowly, so that the bracket slots under the Torx screw, and push the retention arm back securely into the hook again. This will pop the plastic cover off automatically. Just remember to take your time – this is the brain of your build.

03 Bracket racket

To finish with the CPU for now, we need to work on the back of the motherboard. Gently turn the board over, and make sure you work on a soft antistatic surface, checking that no header pins are bearing the weight of the motherboard. Align the cooler backplate to the mobo screw holes, then turn the board back over again. Once this is secured, we can start adding the stand-off screws. Grab the stand-offs and secure them in place. Then add the Intel brackets to the stand-offs to later fit the pump on to. Make sure these are aligned facing outward from the CPU. Tighten the stand-offs diagonally to secure everything. Diagonal tightening ensures good alignment and is a handy tip for all sorts of tasks. Once done, the CPU and bracket can be left alone for now.

04 RAM time

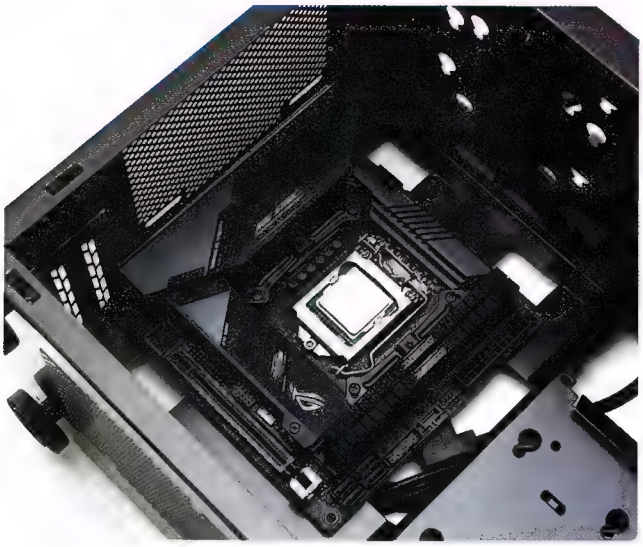
Unlike normal ATX builds, this ITX motherboard only has two DIMM slots, so we can't really mess up the DIMM priorities. That said, you always have to pay attention to the groove at the bottom of RAM sticks. This little groove in the pins will sit in the DIMM slots in one position only. Before inserting the sticks, make sure the clips on each end of the slots are opened – this is a very easy process. Then slot the sticks into place, push down, and you get a nice satisfying click at each end. There you have it – the DDR4 RAM sticks are secured and ready to battle against all of your Chrome tabs. For our build, we are using two 8GB sticks, which should handle all your browsing and gaming needs.

05 Heat stink

Moving on to the other form of memory in our build, we have our SSD. This Samsung 980 Pro is a neat part of our machine. As with all components, we have to handle it delicately; it's an easy step, but unfortunately not as straightforward as a USB drive install. First, we need to take off the heatsink. This is secured by two screws on the plastic clasp. Loosen these, then slide the ROG-branded clasp off, and remove the remaining screw at the opposite end of the heatsink. Once this is done, we can now gently take the heatsink off and put it aside for now. When doing this, be careful of the seven-pin connector on the underside. The last thing you want is to end up with no storage, right? Make sure the sticky part of the heatsink is facing upward, in case any of the adhesive protection layers have come loose.

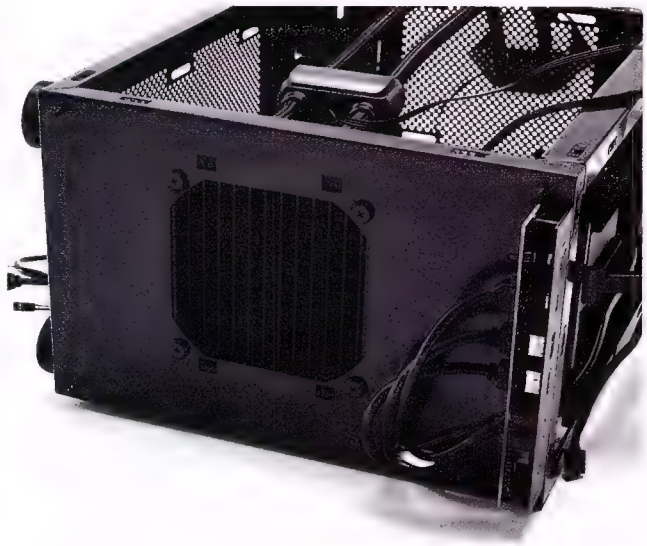
06 SSD installation

Now that the heatsink is out of the way, we can insert the SSD into the motherboard. This M.2 SSD is pretty easy to install. Insert the drive into the connector at a 30-degree angle, making sure it is facing up. If it seems too tight, it probably isn't at the correct angle. We don't want to sound like a broken record, but take your time. Once inserted, it needs to be secured in place with a tiny M.2 screw. Take the heatsink and screw it back down, performing the previous step in reverse, and hey presto: Our SSD is ready for action.



07 Mobo meet case

Mini-ITX builds are, as you'd expect, mini. This makes fitting anything into place a lot more awkward and scream-worthy than a standard build. So, as you can imagine, fitting this motherboard was a joy. First off, we need to add the I/O shield to the open case slot. This is the easy part. Then we have to lower the board into place and screw down each of the corners into the case stand-offs, using the screws provided. We recommend using a long-nose magnetic screwdriver. Everyone has dropped screws into a tight space at one time or another, and having a magnetic tool helps a lot when recovering them. With the motherboard installed, it's nice to see the build coming together.



08 Adding the radiator

One of the biggest jobs for this build is installing our radiator into the case. With little room for maneuver, this can be a particularly frustrating part of the process. Luckily, with the front panel already off, things shouldn't be too tricky. The radiator will go into the front of the case and sit just below the PSU bracket, side-on, in order to fit better beneath the power supply. With the provided wide-top screws, tighten this on to the existing holes in the case with the rubber grommets. Be sure not to overtighten these, because that would nullify the damping effect of the aforementioned grommets. Another tip is to rest the pump block and tubing across the case when fitting the radiator, so they don't get in your way.

09 Pump it up

Now we need to head back to our CPU and add a little thermal paste to its shiny face. Don't be alarmed – this can be quite daunting, but just trust your gut (and us). Grabbing the thermal paste syringe, squeeze a small pea-sized drop on to the center of the CPU, then lower the pump's thermal plate on to the processor, and align it with the stand-offs. Be sure to give it a tiny bit of pressure when resting it in place, to ensure an even spread of the thermal paste across the CPU. Then secure this in position by tightening the screws at opposing corners in order. Our cooling solution is now done, and we can leave the CPU alone.

10 Power Time

Without power, we just have a glorified metal box with some fancy interior parts, as cool as it might look. Our power supply has to be located slightly differently from most cases – it has to sit above the radiator, at the front. It screws in at six points to the metal lip on the other side of the case. You need a thin magnetic screwdriver to reach some of the screws, otherwise you can only tighten the four corner ones, which should be sufficient. Once the PSU is secured, plug in the extension kettle cable that's built into the case.

11 Case Cables

You may be wondering when we're going to add the GPU. Well, be patient, because we need to attach the remaining case cables first. To start, we'll fit the front I/O cables. Thread these through to the motherboard and fit the USB, USB-C, HD audio, and power/reset switch connectors. The pins for these headers are fragile and can bend with too much pressure. Fit them securely but bear this in mind. One cable out of place can prevent your whole build from booting, so pay close attention to the right headers. Next, we need to fit the AIO cables to the motherboard's headers. There will be AIO_PUMP, CPU_FAN, and CHA_FAN connectors for this.

12 Rear Cable Management

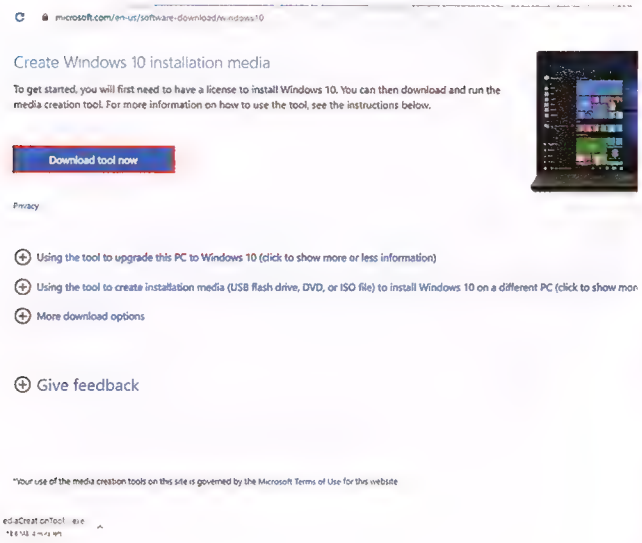
Now we can add the GPU – despite it being a squeeze in this case, the process isn't too difficult. We need to take off the rear clasp that covers the blanking plates on the back of the chassis by removing the thumbscrew, then take away the blanking plates. Take your GPU and slot it into the open PCIe slot, making sure the connector end lines up with where the blanking plates were. With a gentle push down, it will securely click and lock into place. Screw the rear of the GPU into the case with the screws from the blanking plates. With everything in place, the metal case clasp can be returned and screwed back down.

13 Barely Managing

The last step inside our case is to connect the PSU cables to the motherboard and GPU. PSU cables can be quite chunky, so if you can spend a little more cash and get custom-length cables that look tidier and fit better, go for it. Run all the cables through the back of the motherboard to keep things away from the front. The motherboard cables can be thick and inflexible, so fitting them at tight angles isn't exactly the most fun task. It's a little cramped in our Mini-ITX case, but what did we expect? After the ATX and CPU cables are installed, we can add the PCIe cables into the graphics card, and that's it for the PC's internals.

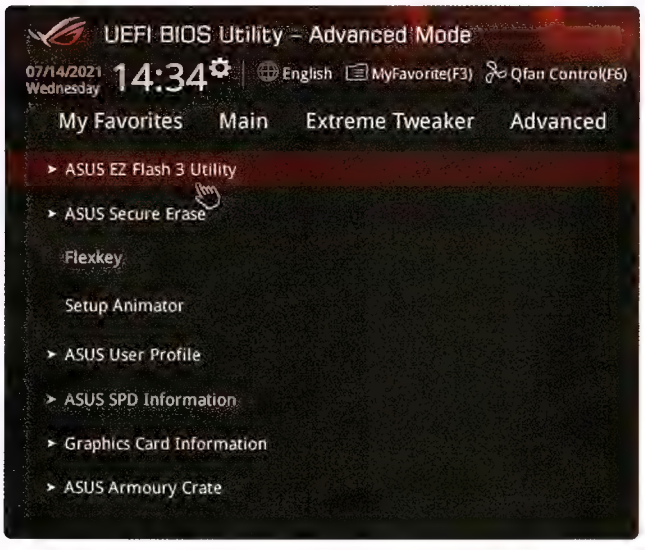
14 Popping Panels

Our case is looking a little too naked for our liking, so let's pop the panels back into place to finish off this mini build. We need to focus on the front first and install the dust filter. It's a part that is overlooked by many, but it keeps a lot of dirt and dust from entering our precious machines. Every once in a while, it's a good idea to remove the dust filter and clean it to keep your PC running smoothly. The first panel to pop on is the front, which secures back in place by replacing the plastic clasp pins on either side. Next, put the side panels on, followed by the top. The case is now looking glorious once again, and is ready for the software side of things.


Create Windows 10 installation media
To get started, you will first need to have a license to install Windows 10. You can then download and run the media creation tool. For more information on how to use the tool, see the instructions below.
Download tool now
Privacy
Using the tool to upgrade this PC to Windows 10 (click to show more or less information)
Using the tool to create installation media (USB flash drive, DVD, or ISO file) to install Windows 10 on a different PC (click to show mor
More download options
Give feedback
"Your use of the media creation tools on this site is governed by the Microsoft Terms of Use for this website

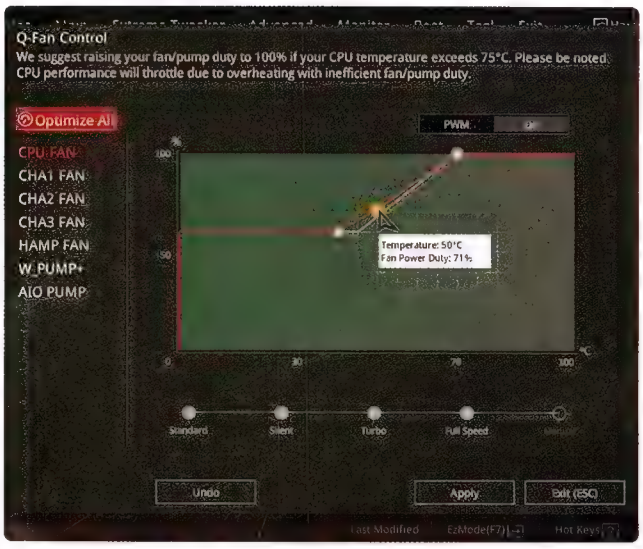
15 Windows USB boot

You can't really avoid this step. Every PC setup requires a fresh OS install to get things going. To help with this, it's handy to have another PC ready to download the required software on to a USB drive of at least 8GB storage capacity. Head over to Microsoft's website and search for "Create Windows 10 installation media." Download the file, open up the software, and you will see a screen that says: "Getting a few things ready." After accepting the terms and conditions, wait again. It gives you the option to upgrade that PC now or create installation media for another PC after the second time. Click the second option and proceed. On the next screen, leave things as default, then you can choose which media to install Windows 10 on; click "USB flash drive" to find your drive, click "Next," then it starts to download.



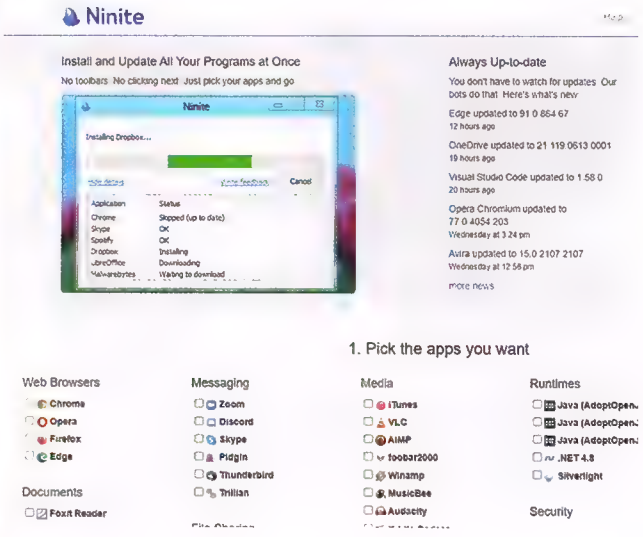
17 Update the BIOS

You don't have to update your BIOS. Usually, if you're buying a brand-new board, it should come pre-flashed with the latest version, but if not, boot up a separate PC or laptop and head to the mobo's support page on the manufacturer's website to download the latest BIOS update. Extract it to your USB drive (this needs to be formatted to FAT32; you can use the Windows Installer drive for this), and then placed into a folder named "BIOS." Insert the drive in the new build and restart it. When booting, mash the Delete key until you see the BIOS menu. Click "Use USB to flash BIOS M-FLASH." Accept and run it. The M-Flash screen should appear; click the folder for the BIOS update you created, and open it. Select "Yes" and it begins updating. Leave this to do its thing. Once it's done, the system restarts, and you're good to go.



16 Open the BIOS

When the download is complete, take the USB drive out and insert it in the new build. Turn the new machine on and you're greeted by the BIOS. Your PC's BIOS interface contains all sorts of vital data and settings that can be altered to suit your needs. A good thing to dive into is the fan curves, which can be altered to make the PC run more quietly – do some research to find what suits your build. Going back to the Windows install, find the boot priority section of the BIOS, and arrange the order to make your USB drive the priority boot drive, then restart the PC. This should boot up the Windows installation and welcome screen for first-time use. Name your PC whatever you want. You don't need to purchase a Windows key yet, so keep running through the setup steps until you get to your fresh Windows 10 desktop.



18 PC starter pack

After all these steps, you should have a sweet-looking mini machine that's running well. There's just one thing we need to do before we wrap up this build: Install some software. Fortunately, there's a swift one-stop-shop solution to download a bundle of starter software for your PC: **https://ninite.com**. Head to the site, select which popular programs you'd like to download, and just like magic, everything starts installing. The great thing is that it does this all in the background, it says no to any toolbar and extra junk options, it installs the latest stable version of each app, and it downloads them from each publisher's official site. Does it sound too good to be true? Well, it isn't; it's free and super-easy. Nice work, Ninite.

1 To improve this build, we would get our hands on the Asus Z590i to provide superior future-proofing.

2 With an updated motherboard, we would also add an 11th-gen chip. Why not?

3 Luckily cable management isn't the most vital requirement for this windowless build, but aftermarket custom cables could help any future changes by giving us more room to work.

4 Two sticks of 16GB RAM would, again, be beneficial in terms of future-proofing this PC.

Good things come in small packages

In an ideal world, we would rather be running an 11th-gen CPU in our new build, with a later Z590i motherboard. This would have certainly made more sense for our SSD. Regardless, our rig is still a more-than-capable fighting machine.

Being a Mini-ITX build, it certainly was more difficult and awkward than a typical ATX case. Fitting everything to the motherboard was easy enough, but when it came to fitting parts inside the chassis, some niggling issues arose. The obvious lack of space meant that we had to take things more slowly. Every component we added decreased the available workspace, resulting in even more stress. This is where our long-necked magnetic screwdriver came in. Screwing down the motherboard was not as daunting thanks to this tool. The cooler created most of the issues inside the case, largely due to the inflexible nature of the radiator tubes and having to fit said tubing into an already-cramped area. Don't let these issues put you off your own Mini-ITX build, though, as they are fun PCs to own.

Benchmarking

For a mid-budget Mini-ITX build, the CPU and GPU are more than good enough for producing a reliable 60fps-plus experience at high graphical settings. Yes, at 4K the i5-10600K paired with the Zotac GeForce RTX 3060 Ti can't quite reach the frames we would love to see, but it only falls marginally short of the ideal gaming targets. Up against a very similar build with an AMD Ryzen 7 3700X, the Intel build just wins. However, as we said earlier, our Intel chip doesn't support PCIe 4.0, making the AMD chip a better bet for high-speed data transfers.

Another area where our Intel build reigns over the AMD rig is the sequential read and write speeds. This has to be down to our Samsung 980 Pro SSD. Again, it is overkill, and unlike the CPU, this is future-proofed with PCIe 4.0 support. Luckily, the Samsung drive is PCIe 3.0 backward compatible, and works fine in our build. Due to the 980 Pro running at PCIe 3.0 speeds, it's slower than it could be, but does hit the Gen3 speed limit on sequential writes (uncommon for PCIe 3.0 drives). Regardless, this SSD is great and certainly improves our build overall. The Be Quiet! PSU and cooler also help to keep this build running at comfortable levels of sound and temperature.

Final points

Our benchmarks prove you can get a PC with solid performance inside a small form factor without having to spend too much. We're happy with our results, but they do highlight problems in a few areas. If we'd got a newer Asus Z590i board that supports 11th-gen chips, we feel we could have hit that sweet spot of 4K gaming above 60fps. This would also make more sense for our SSD, which would run better with PCIe 4.0 support. Also, if we upgraded those parts, we would swap the existing RAM sticks out for a 2x 16GB kit. On the whole, though, we have produced a neat little gaming machine in an awesome-looking industrial case. The carry handle makes it ideal for LAN parties, too, if they still exist in a post-COVID world. ■

	Zero-point	Mini Maestro
Cinebench R15 Multi (Index)	2,185	1,443
CrystalDisk QD32 Sequential Read (MB/s)	3,522	3,542
CrystalDisk QD32 Sequential Write (MB/s)	2,988	3,482
Middle Earth: Shadow of War (fps)	52	54
Total War: Warhammer II (fps)	48	51
Shadow of the Tomb Raider (fps)	53	50
Red Dead Redemption II (fps)	47	49
Assassin's Creed Valhalla (fps)	38	35

Our zero-point consists of an AMD Ryzen 7 3700X, 16GB DDR4 @ 4,133MHz, a Zotac GeForce RTX 3060 Ti 8GB, and a 1TB ADATA XPG Spectrix S40G M.2 PCIe 3.0 SSD. All tests were performed at 4K on the highest graphical profile.

Quick Tips

Tech troubles tackled

The *APC* team field problems across the spectrum of devices and software. Learn a new trick or fix you can use.

Malware begone!

I have a very frustrating problem with some adware/malware. My pastor has an older PC running Win 10. It has the free versions of AVG and Malwarebytes installed, along with Windows Defender. A year or so ago, she started getting ads for Staples.com popping up, taking over the Chrome browser. We noticed that while she was working on a document, the Run command prompt would pop up in the lower-left of the screen and she would be taken to Staples.com. I checked the Run command history and found several variations of Staples.com in the list. Some were misspelled. I ran deep scans with AVG and Malwarebytes but found nothing. I erased the Run history, cleared the cache, ran CCleaner, and hoped for the best. Three days later, it happened again, and she was unable to use the computer, as it just kept running the Run command by itself. I scanned her USB drives and a desktop drive that is connected, with nothing found.

Finally, after trying a search for anything with "staple" on the entire computer and finding nothing of note, I did a complete reinstall of Windows 10 without saving any old files. After reinstalling all her software, the machine worked great again. Until recently. The Staples Run command has reappeared. Clearly, something is infected, but scans don't find anything. Can you offer any suggestions as to how to locate the culprit file on USB connected drives?
Gerry Exstein

***APC* Responds:** This bears all the hallmarks of a typical virus infection – it might be some random script on your pastor's computer, or it may indicate someone has given themselves remote access to the PC and is manipulating it externally. Either way, you need to close that security hole. *APC* recommends a complete wipe clean and reinstall using Windows installation media, making sure you format the Windows drive before reinstalling Windows on to it.

Once done, up your pastor's security – free software is all well and good, but it's clearly not protecting you here. Choose a comprehensive security suite – such as Bitdefender Total Security – that includes additional protection. In the case of Bitdefender, it contains multiple technologies that actively look for suspicious behavior; in some ways, it's over-protective, but in this case that's preferable to being subject to another attack. In addition, its firewall is two-way, which means it monitors outgoing connections from the PC as well as incoming ones, so if someone has implanted a remote-control tool on your PC, Bitdefender should spot it.

ESET SysInspector enables you to see what's running on your PC.

Also make sure security is tightened in other areas. First, physical security. Does anyone else have access to the PC? If it's being shared, your pastor should lock off her own account with a password – which should be changed in case it's been shared with others – then set up guest access or standard (non-administrator) accounts for other users. Also, make sure any shared folders are password-protected, so only trusted contacts have access, and check that no remote-control software has been installed, and that Remote Desktop – not applicable on Windows 10 Home Edition – is disabled. To do this, type "remote access" into the Search box and click "Allow remote connections to this computer" – ensure "Don't allow remote connections to this computer" is selected.

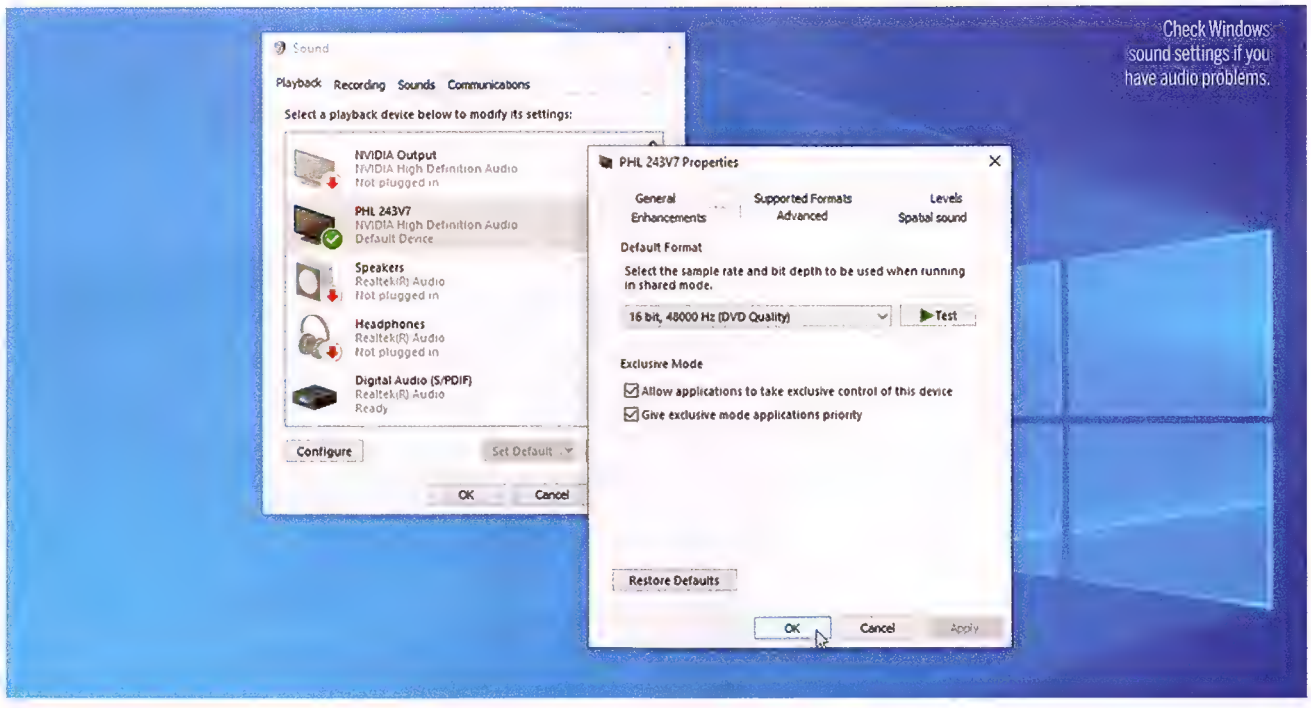
If the problem comes back, use a free tool called ESET SysInspector (**www.eset.com/int/support/sysinspector/**) to log all running processes and services – it'll flag any potentially suspicious ones (along with suspicious network connections), which will hopefully provide tell-tale traces of where this infection originated.

Sleep reboots

My Dell Inspiron 15 7000 two-in-one laptop sometimes reboots after opening the lid. Control Panel is set to put the computer to sleep when the lid is closed. There's no specific time delay – it might do it after just a few minutes of having closed the lid or after a couple of days. Event Viewer simply says that the shutdown was unexpected. When I close the lid, I usually only have Chrome running with a few extensions. How do I diagnose what's causing the reboots?
Doug Ochsner

***APC* Responds:** First, make sure your BIOS and drivers are all up to date. If the problem persists, try resetting the BIOS to its defaults. Still no luck? Verify that hybrid sleep has been disabled (it should be by default on laptops): Go to "Start > Settings > System > Power & sleep" and click "Additional power settings." Click "Change plan settings" next to the current plan, followed by "Change advanced power settings." Expand "Sleep > Allow hybrid sleep" and change the setting to "Off." Click "OK." If you ever put your laptop to sleep in battery mode, repeat for that power plan, too.

If this doesn't work, try putting the laptop to sleep manually via the "Start" button – if it randomly restarts from here, it's worth running a diagnostic to see what's waking it up (and then subsequently causing it to crash). Right-click the "Start" button and choose "Command Prompt (Admin)." Type the



following to generate a power efficiency diagnostics report and save it in your Downloads folder:

```
$ cd %homepath%/Downloads
$ powercfg /energy
```

Wait around 60 seconds for the report to be generated, then open the Downloads folder and double-click the energy-report.html file to view it in your browser. Don't be alarmed at the number of red errors and yellow warnings – many represent normal behavior (such as your drive imaging tool refusing to allow your PC to sleep while it's running). However, they may also reveal potential causes for the reboot – could the reboot be caused by a background app trying to run, for example? If so, check the web for possible causes – is it a known problem with that app, in which case there might be a patch, or failing that, try disabling whatever part of the app is waking your PC, or try uninstalling it to see if that resolves the problem.

One final thing: Make sure you run a full disk check of drive C. All those reboots may be leading to file corruption issues, in which case a simple chkdsk should fix it – set this up via the same administrator command prompt as earlier:

```
$ chkdsk c: /f /r /x
```

You'll be prompted to schedule disk check for the next reboot, so press Y, then restart your PC, and monitor the check to see whether any errors are found (and fixed). If they are, you may find that the sleep feature now works correctly, too.

App sound issues

I'm running Windows 7 Pro – fully updated – and have a long-standing issue. I get no sound in any apps like VLC (fully updated), as well as all other video player software. But I can get sound using "Open with" and any browser, no problem. All sound works in all videos in all browsers; that's been my workaround. Sound also works for videos in iTunes.

I have tried reinstalling the sound driver (Dell XPS 3770) and uninstalling/reinstalling. When I try to mess with audio settings in VLC, VLC crashes. No sound setting adjustment works at all in other players. Seems like a registry corruption issue, maybe due to a Windows Update long ago. This Win 7 install is very old. I'm reluctant to mess around with registry settings about which I know nothing.

Any help appreciated – it's a stumper for me!

Alan Perla

***APC* Responds:** Our temptation is to say wipe clean and start again. Given the age of your Windows 7 installation, it's long past its reinstall-by date (more on that shortly). That said, there are some quick tweaks you can try. First, could it be possible that your playback and output devices have become garbled somehow? Maybe your video player's audio output is being re-routed to your headphones jack, for example – try plugging in a pair of headphones and listening in.

To check this out in more detail, open the Sound Control Panel – check which is your default device on the "Playback" tab and change it, if necessary, by selecting a different device and clicking the "Set Default" button. You may also want to click "Properties" and explore the various tabs to see whether any other settings may need reconfiguring.

If you suspect system corruption, try running "sfc /scannow" under an administrative command prompt to identify potential corrupted system files. Beyond this, messing with the registry's a no-no unless you know exactly what you are looking for – and don't bother with registry cleaning tools; they're more likely to introduce problems than actually solve any.

Instead, take a fail-safe image of your current install with Macrium Reflect Free, use an app such as CloneApp (**www.builtbybel.com/ms-apps/cloneapp**) to back up key program settings, and make sure your data is also backed up – using Windows Backup & Restore for simplicity – if it's stored on the same partition as Windows. Make sure you've got the latest version of all available drivers for your PC as well as your program installers (if any apps required activating over the Internet, find out what you need to do to transfer the license to the new install – you may need to deactivate them first, or contact the developer to inform them of your plans; take your drive image before you deactivate the license, just in case).

Once done, format the drive, reinstall Windows 7 from scratch (if your install media doesn't include SP1, download a fresh ISO file to burn to disc from **www.microsoft.com/en-us/software-download/windows7**), then install Macrium Reflect before taking a fresh drive image. Next, install all available updates and drivers, taking a differential drive image, before restoring your backups and reinstalling your programs and settings. Keep testing the sound throughout, but *APC* suspects that wiping your drive clean and starting again from scratch should resolve the problem once and for all. ■

WINDOWS

Prepare your PC for Windows 11

There's a new OS in town, you can get it for free, and you're going to want it. Ian Evenden explains the steps you'll need to take.

YOU'LL NEED
A PC with the correct CPU
See Step 1 for details.

Windows 11 is a handsome beast, reminiscent of Windows 10, yet still its own thing, with more to recommend it than a centered taskbar and rounded corners on its windows.

Anyone on the Windows Insider Dev Channel will already have had a build of 11 arrive through Windows Update. It is, at the time of writing, quite stable, but is not exactly what you'd call feature-complete. Still, it makes an interesting thing to have in a virtual machine or installed on a spare PC so you can bring it out at parties and impress your friends.

There's a snag, however. It's not yet implemented in the preview build, but Microsoft says this new OS will rely more heavily on hardware security features than any before it. Specifically, we're talking TPM (Trusted Platform Module) 2.0. This can be added to a compatible motherboard with a dongle, or enabled in the BIOS of others. For many self-built PCs, however, it will be a headache. Let's find out about that, and what else you should do before upgrading.

Is your CPU up to it?

Microsoft has published lists of CPUs that are compatible with its latest baby. They're short, but include AMD Ryzens back to the 2XXX series (Zen+, though Microsoft often refers to "Zen 2") and Intel Cores back to eighth-gen (Coffee Lake), plus a handful of Athlons and Celerons unlikely to be of interest to readers of APC. There's a list of Qualcomm chips, too, paving the way for the inevitable takeover of everything by ARM designs (a version of Windows 11 is already running on the Raspberry Pi 4, but currently lacks Wi-Fi functionality). This limited selection of CPUs is probably something to do with their compatibility with the new Windows Driver Model, and if yours is on the list, great. If it isn't, well, Microsoft says it will keep on updating Windows 10 for some time, but you'll miss out on the ability to run Android apps on your PC, the implementation of Direct Storage (a direct link between SSDs and your GPU for faster loading in games) from Xbox-land, and rounded corners on your windows.

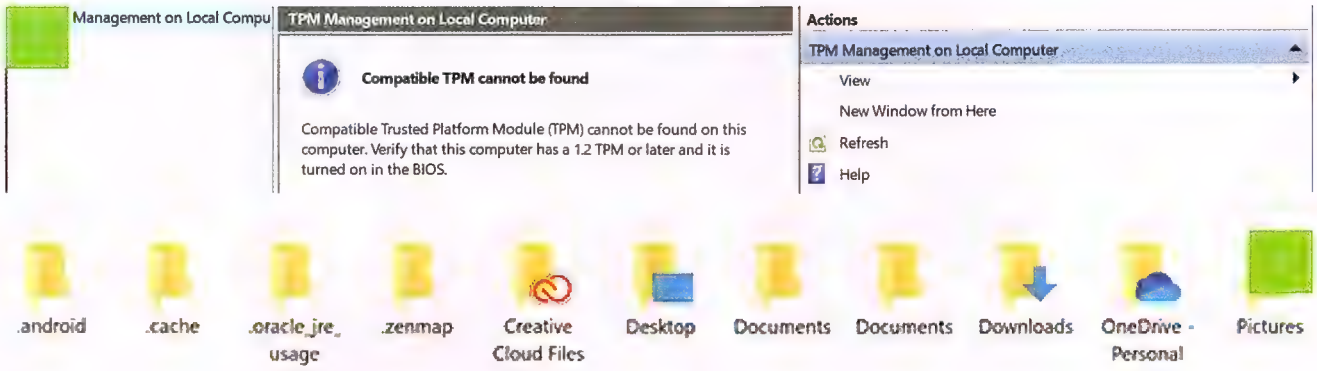
The dreaded TPM

Even if your CPU is on the list, it doesn't mean you're completely in the clear. You need a GPU capable of dealing with DirectX 12 (which is most of them) and you need hardware security. No one knows why Microsoft has gone so hard for TPM this time around, but it has, and PC builders are being left to deal with it. There's good news, though: If your motherboard has a TPM socket, you can add it with a $20 dongle **[Image A]**. (As we write, price-gougers are out in force preying on the panic-stricken, but Windows 11 isn't here yet, and more stock will surely arrive.) Many motherboards actually have it built in, and you can activate it in the BIOS – which must be UEFI – under "Advanced Mode > Settings > Security Device Support," or something similar **[Image B]**. There's a quick way to check whether yours is activated: Within Windows, open a Run window or hit Win-R, and type tpm.msc . The window that opens will give you a quick yes/no answer about whether hardware security is on, and what level it's at **[Image C]**. Remember you need TPM 2.0; the previous 1.2 standard won't cut it. The various motherboard makers have been

WHY, WHY, WHY?

Microsoft is being tight-lipped about why it has restricted Windows 11 to CPUs made in the past four years or so, but it probably comes down to two things. Windows 11 PCs are meant to be secure. Very secure, with TPM 2.0 and virtualisation-based security, which isolates a region of memory for Windows to operate its security solutions in, so they can't be accessed even through an OS vulnerability.

MS also doesn't want Windows 11 PCs to crash, and one of the most common causes of crashes is a bad driver. The concept of Driver Package Isolation is not new, but we can expect to see much more of it in Windows 11. It means drivers run from a centralised Driver Store rather than System32, can only write data to system-mandated areas, and can only interact with other drivers using system-supplied functions or interfaces.



publishing lists of their compatible chipsets, too, so you should be able to find out fairly quickly if you can upgrade, or need to buy a new PC.

Health check

Once upon a time, Microsoft released a little app called PC Health Check that claimed to tell you if your PC was ready for Windows 11. It did this, but in an enragingly vague way that didn't actually tell you why your pride and joy had failed the test. As we write, Microsoft has withdrawn the app, but its replacement has yet to appear. We await more detailed information about our PC's failings with bated breath.

A few other bits

Got 4GB of RAM? How about 64GB of storage? Screen greater than 720p? You're all set. The minimum requirements for Windows 11 just happen to be the same as those for Microsoft Office and Teams, making it look like MS is going for some sort of synergistic joined-up experience.

Getting ready for an upgrade

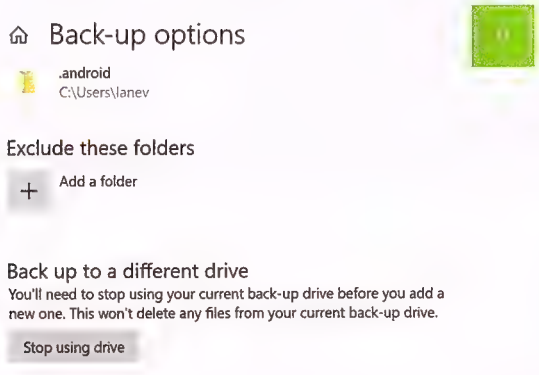
Windows 11 is similar enough to Windows 10 that we expect an in-place upgrade will be possible, keeping all your documents, and possibly all your installed apps, where you left them. The way it was rolled out to Dev Channel users supports this – it appeared in Windows Update in exactly the same way a new version of Windows 10 would. Getting a new OS, however, can be an opportunity for a few other upgrades, and a new, fast, SSD boot drive wouldn't be out of place to make Windows 11 feel even more responsive. Especially now the prices of PCIe Gen 4 models have fallen to levels normal humans can afford.

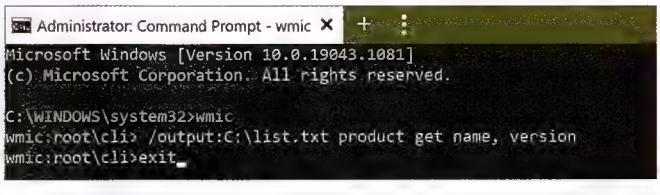
Serial numbers

Reinstalling all your apps is a pain, but it goes far more smoothly if you've got your serial numbers backed up. This goes for Windows itself – we don't know what the punishment will be for running an unactivated build of Windows 11, but it's not outside the realms of possibility that it will be harsher than just not being able to change your desktop background. If you've used your Microsoft account for activation, it might just be a case of logging in and selecting the serial number you want to transfer. We won't know until the retail build is here. Adobe apps let you manage installations from the Adobe account management website, so you can deactivate your old Win 10 PC and activate the new Win 11 one, though you can have a CC subscription on two PCs at once with no penalty.

Backups

You are already backing your documents up, aren't you? Cloud storage systems such as OneDrive and Google Drive make it easy to keep a rolling off-site backup of your documents, while Windows' own File History will do the job if you prefer an external hard drive or NAS. File History even restores the latest versions of your files to their original locations on your hard drive if you select "Settings > Backup settings > More options > Restore files from a current backup" **[Image D]**. Why this isn't just called "File History" is beyond us, as it makes searching for the settings far more difficult, but perhaps Win 11 can fix this. You're shown your backed-up folders as they are on your backup drive, and you can restore them all or a folder at a time **[Image E]**. ■


Back-up options
.android
C:\Users\lanev
Exclude these folders
Add a folder
Back up to a different drive
You'll need to stop using your current back-up drive before you add a new one. This won't delete any files from your current back-up drive.
Stop using drive



LIST INSTALLED APPS

If you decide to go with a clean installation of Windows 11, you'll need to reinstall all your apps, and it can be useful to see exactly what you've got installed on your PC, especially if it's been a while since you set it up.

To do this, run Command Prompt as an administrator, and type **wmic** and Enter. Once the WMIC prompt opens, type **/output:C:\list.txt product get name, version** then hit Enter. You can replace **C:\list.txt** with another file name or output directory. Close the WMIC window once it's finished. A list of your installed software should be available as a text file in the location you provided for the output file. You also get a version number, so you can check whether updates are available when it comes to doing the reinstall.

APPLE MAC

Find and delete duplicate files and photos

Save space with Find Duplicates in Parallels Toolbox.

IT WILL TAKE
10 minutes

YOU WILL LEARN
How to find and delete duplicate files

YOU'LL NEED
Parallels Toolbox for Mac ($27.99/year), macOS 10.12 or later

It doesn't take long to fill your Mac's hard drive or solid-state drive with clutter. Old photos or work files can quickly take up hundreds of megabytes of precious storage space – take a look at your folder that contains email attachments, you'll find that alone is taking up a surprising amount of GB. One common problem is that many of us tend to create duplicate versions of files that people send us – some photos from a friend, or a bunch of PDF files from a work colleague. There's a tendency to automatically create duplicates of photos and files that we need, say, for work, keeping the originals safe in one folder while editing the duplicates in another. There are a number of apps that can help you to find and delete duplicate files, but the one we go to most is part of the Parallels Toolbox suite (from **parallels.com**). Toolbox costs $27.99 per year, but it includes more than 30 different apps and utilities, and its Find Duplicates tool works very much like Spotlight, so it feels familiar and easy to use. Toolbox also offers a seven-day free trial so that you can check it out first.

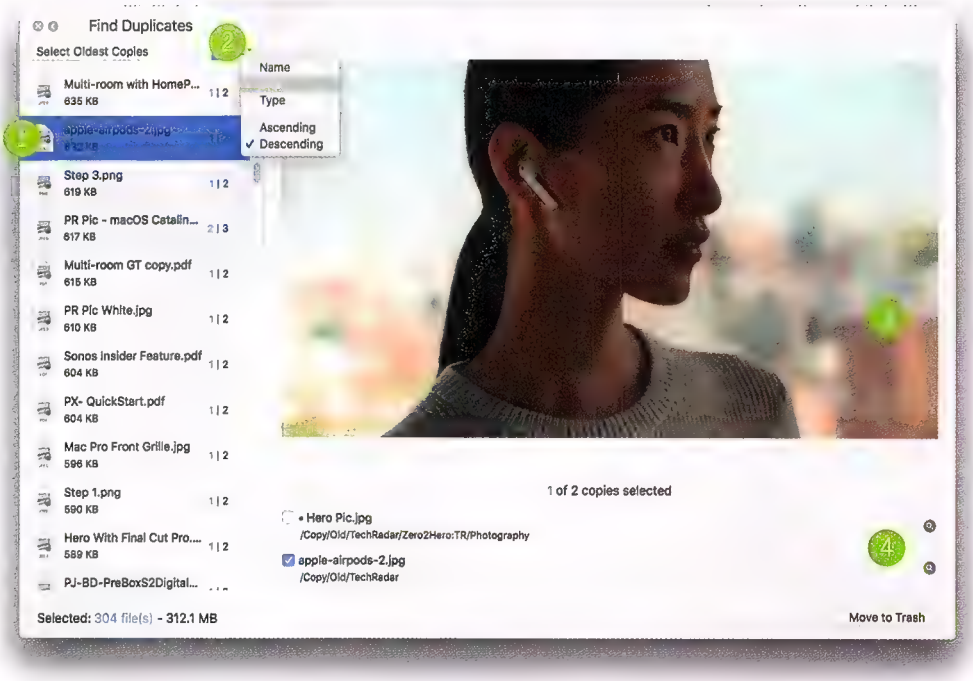
EXPLAINED... The Find Duplicates feature

1 **SPOTLIGHT ON DUPLICATES**
The tool works like Spotlight, with a list of files on the left and a preview of each file on the right.

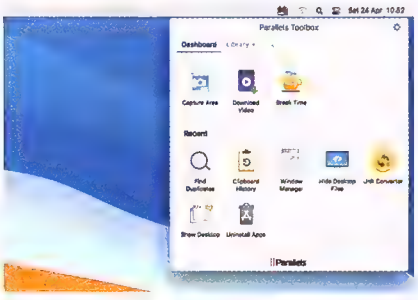
2 **SORT AND DELETE**
You can sort all your duplicate files by file name, size or type, and choose which ones to delete.

3 **WHAT'S IN A NAME?**
The app doesn't just look at file name – it looks at the actual content of each file.

4 **FILE PREVIEW**
You can view details of each duplicate that you find, and preview the file before deciding whether to delete it.

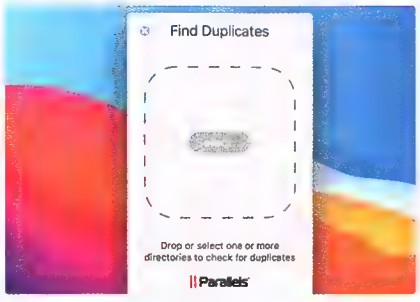


HOW TO Find and delete duplicate files



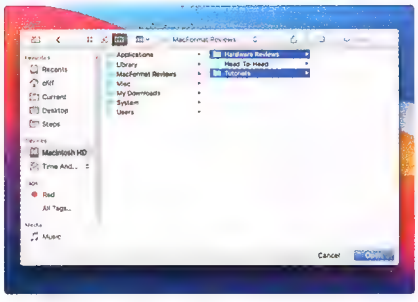
01 Launch Find Duplicates

Parallels Toolbox contains a large collection of useful tools and utilities, and version 4.5 includes a new 'dashboard' that automatically shows the tools that you use the most. Let's just click on Find Duplicates to launch it.



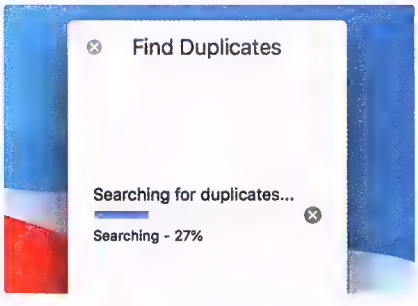
02 Start searching

The Find Duplicates tool is very straightforward. You can search any folders for duplicate files either by dragging and dropping them into this window, or you can click Select to open the Mac's standard Open dialog box.



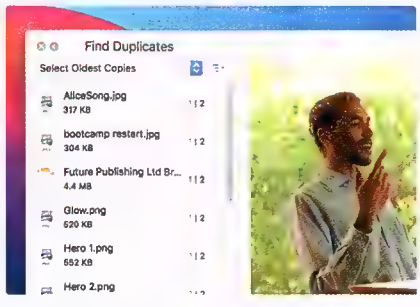
03 Select folders

You can select multiple folders where you want to search for duplicate files, and Toolbox will also search any additional sub-folders stored within those folders. Just click the 'Search for duplicates' button to start.



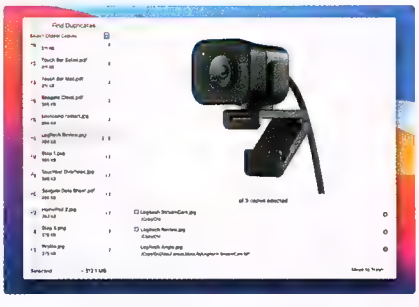
04 Save results

Here it's taken Parallels Toolbox 30 seconds to scan a folder containing 10GB of old work files. Toolbox stores the results of that scan too, so that other scans in the future will be faster even if you add more files to that folder.



05 Spotlight on duplicates

As mentioned, the Find Duplicates tool works in a similar fashion to Spotlight, which makes it feel familiar and easy to use. It shows a list of the duplicate files it has found on the left, with a preview of the file on the right.

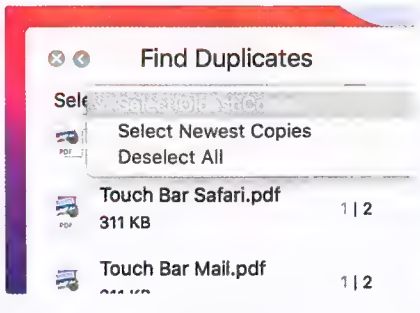


06 Look beyond the name

The app doesn't just look for files that have the same name. It also compares the content of each file. Here it has found three identical photos of this webcam, even though the three files all have different names.

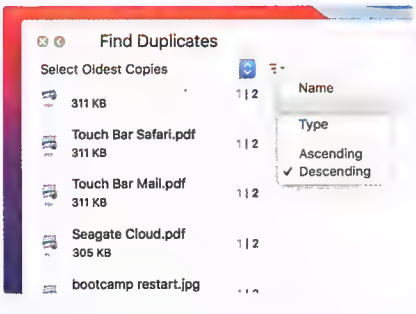
07 Go auto or inspect

By default, the app selects the oldest versions of every duplicate file to delete, and leaves the newest version alone. It can automatically delete all duplicates for you, but you can take a closer look at each file if you want.



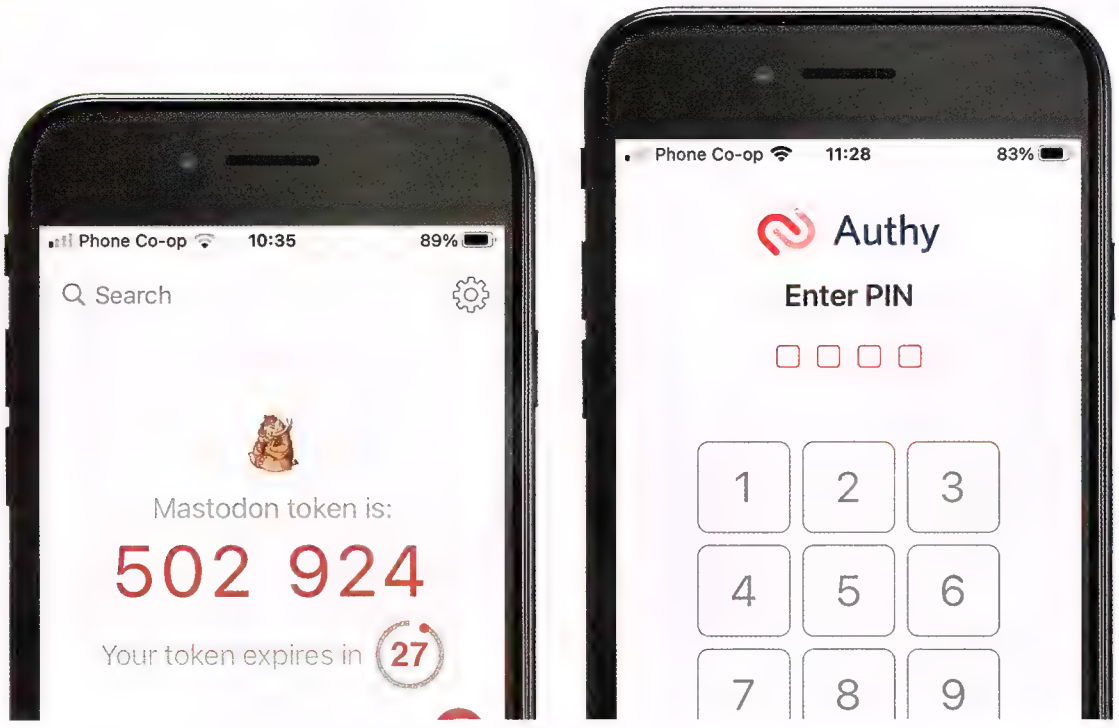
08 Make your selection

There are a number of other options available when searching for duplicate files. Instead of selecting the oldest file copies, you can tell the app to select the newest files instead, or tell it not to select any files at all.



09 Sort and find files

If you're looking for a particular type of file, then you can speed things up by sorting through files in alphabetical order, by file size or file type. You can also arrange the list in ascending or descending order. ■



APPLE iOS

Protect accounts with 2FA

Add a secondary layer of security to your online accounts and services.

IT WILL TAKE
10 minutes

YOU WILL LEARN
How to set up Twilio Authy to generate and supply 2FA codes

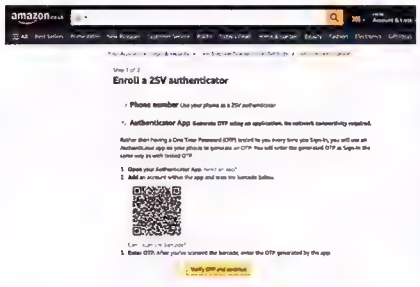
YOU'LL NEED
iPhone running iOS 11 or later, Authy (Free)

Two-factor authentication (2FA) is a form of additional verification to protect your online accounts in case your password is compromised. Verification can take several forms: 2FA is the most popular, but others include receiving a confirmatory email or SMS message to your phone, or the need to complete logon using a secondary device.

2FA links your phone to your account via a special authenticator app that generates rotating numerical codes (six-eight digits) that change every 30 seconds. After entering your password, you'll be prompted to check your app for the code, which you input to complete the logon process. There are several apps available – we've chosen Twilio Authy because it supports multiple devices and secure backups. Once you've downloaded it, you'll need to supply your phone number and email, then enter the registration code you receive via phone call or SMS to verify your account.

NICK PEERS

HOW TO Enable 2FA for any supported website

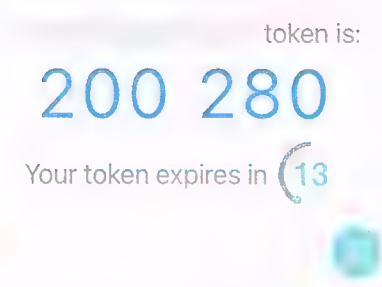


01 Add a 2FA code

Log into one of your online accounts. If it supports two-step verification it's likely to be in the Account or Security section. Switch this on, then choose the Authenticator App option, which should reveal a QR code.

02 Set up Authy

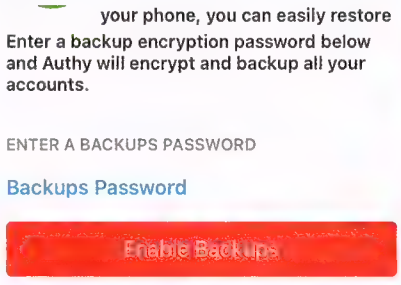
Open the Authy app, tap the Settings button and switch to the Accounts section. Tap the '+' followed by Scan QR Code and use your phone's camera to capture the code which will then set up the new 2FA link.



03 Select logo and verify

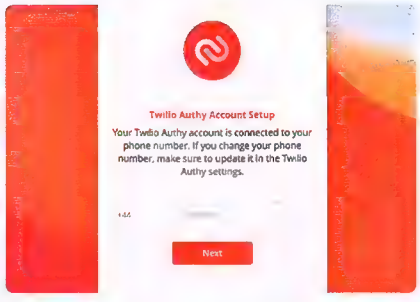
Authy will attempt to identify the service you've connected to and pick a suitable icon. Tap Save and Exit. Your new account should be selected, so type the code into the web page to complete setting up the link.

HOW TO Backup and sync


your phone, you can easily restore
Enter a backup encryption password below and Authy will encrypt and backup all your accounts.
ENTER A BACKUPS PASSWORD
Backups Password
Enable Backups

01 Enable cloud sync

When you add your first account, you'll be prompted to create a password (make it strong – 12 characters minimum – stored in your password manager). Enter it, tap Enable Backups and then retype the password to confirm.


Twilio Authy Account Setup
Your Twilio Authy account is connected to your phone number. If you change your phone number, make sure to update it in the Twilio Authy settings.
Next

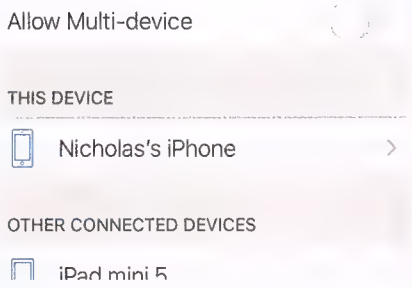
02 Set up backup device

Go to **authy.com/download** to install Authy on your secondary device – this can be on iPad, Mac, Android, Linux or Windows. Open Authy on your new device and enter your country code and number into the boxes.

03 Authorise connection

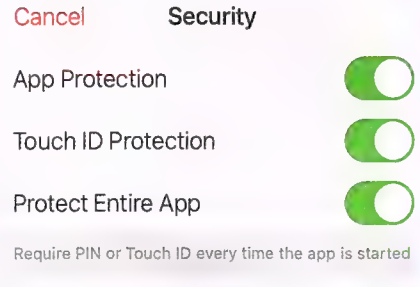
Choose Existing Device to receive verification via your phone. Tap the notification that appears on your phone, then open Authy and tap Accept, then type 'YES' before tapping OK to sync your codes to your new device.

HOW TO Protect your account



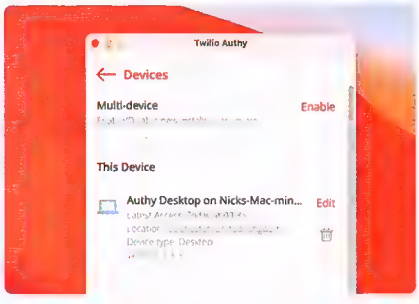
01 Disable multi-devices

Once you've set up your chosen secondary device(s), remove the risk of additional unauthorised devices being added by disabling multi-device support. Navigate to Settings > Devices and switch Allow Multi-device off.



02 Protect app

Next, prevent anyone from accessing Authy should they steal your phone. Navigate to Security > My Account and tap Security. Toggle all the available switches to on, and set a four-digit passcode when prompted here.



03 Review and remove

If a device is no longer required, or gets stolen, then log into Authy on another device and navigate to Settings > Devices. Either tap the device or the bin next to it, then choose Remove Device followed by Yes.

RECOVER YOUR ACCOUNT

Restore access to Authy from your phone.

If you're forced to remove Authy from your primary phone, but later recover the phone successfully, download the app and go through the account verification process as outlined in the main text. After doing so, all your accounts will appear back on your phone, but you'll see they're protected with a lock symbol – tap one and enter your Authy backup password to unlock your account and regain access. If this doesn't work, visit **authy.com/phones/reset** to begin the account recovery process, which can take up to 24 hours to complete. ■

Unlock Accounts
Your accounts are encrypted, enter the password that you have configured for backups below to see your tokens.

LINUX

Use your mobile as a secondary display

Nick Peers reveals how to display your desktop on your phone, tablet or laptop's WebRTC-capable browser.

Not everyone has the desk space – never mind the finances – to afford the luxury of a dual-monitor setup. Adding a second display can, however, revolutionise the way you use your PC.

Deskreen is a free application that provides a clever workaround to this problem, one that makes it possible for you to view multiple windows at once across additional displays without spending anything. Simply put, it enables you to convert other devices, including phones, tablets, laptops, and even smart TVs, into a secondary display for your computing tasks.

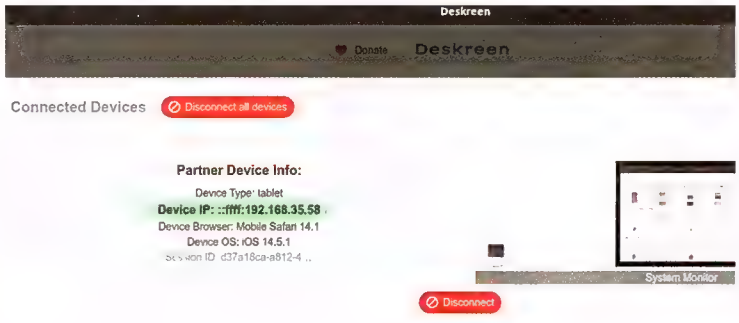
This display can easily mirror your entire desktop so that you can monitor your PC remotely, or you can use it to view a specific program's content alongside your main display. Armed with the right know-how (see the box, below), you can even use it to extend your desktop for even greater flexibility.

Deskreen transmits your display – both X and Wayland windowing systems are supported – to your mobile devices over your local (wired or wireless) network using the WebRTC protocol. Most of the heavy lifting is done by your PC, so even older phones and tablets should work with it.

The key requirement for your mobile is that it has a web browser that supports WebRTC – on Android, that means running Chrome 28 or later, or Firefox 22 or later. If you're hoping to use an old iPhone or iPad, it'll need to run iOS 11 or later.

You can download Deskreen as a .deb or AppImage. The latter, of course, means no installation is required – head over to **www.deskreen.com** and click your chosen download link. Download and double-click the .deb file to install it via Ubuntu Software, or right-click the downloaded AppImage file and choose Properties > Permissions tab to tick 'Allow executing file as a program' before running it for the first time.

On first launch, the main Deskreen window will pop up and you'll be prompted to confirm your language and choose between a light or dark theme. Make your choice and click Continue. The step-by-step guide (below) reveals how to make the initial connection between Deskreen and your remote browser.



Deskreen makes it possible to view selected desktop applications (or your entire desktop) via your tablet or phone.

QUICK TIP
Visit the Deskreen project's Github page (**https://github.com/pavlobu/deskreen**) for the latest releases and information, including links to its user forums for more help and advice if you need it.

Controlling the connection

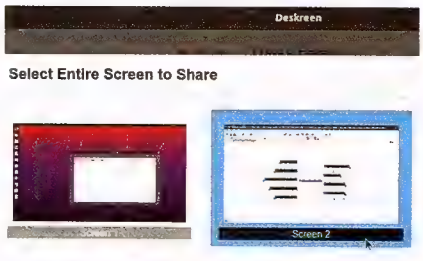
Your browser will display the application window or desktop on your secondary display. If

EXTEND YOUR DISPLAY WITH DESKREEN

By default, when you come to share your entire screen, Deskreen will enable you to mirror it – handy, for example, if you want to keep an eye on several running tasks without being tied to your desk. If your PC's graphics has multiple ports, you can go further by plugging a Virtual Display Adaptor into a spare HDMI or DisplayPort socket. These 'dummy' plugs cost as little as $10 on eBay – make sure you purchase the correct type for your ports.

Once connected, your PC is tricked into thinking a second monitor has been plugged in, and Deskreen will give you the option of viewing this dummy display for real through your connected device. Adding a secondary display like this means you can extend your desktop, enabling you to drag windows from your monitor on to the second desktop to be viewed – and controlled via your mouse and keyboard – directly from your remote display.

The dummy plug option is the simplest way to extend your desktop, but if you're comfortable playing around with a bash script, try Virtual Display Linux (**https://github.com/dianariyanto/virtual-display-linux**). Nvidia users will need to try a different approach – follow the link at the bottom of the read-me file to discover a workaround using Nvidia's TwinView option.



Deskreen's developers are looking at adding Virtual Display support without the need for an adaptor.

you're using it to display a single application window that's hidden on your current desktop then it's a 'dumb' terminal: you can only control it in the usual manner by bringing it to the fore on your primary display using your mouse or keyboard. If you've chosen to display your entire desktop, then it'll simply mirror what you see on-screen.

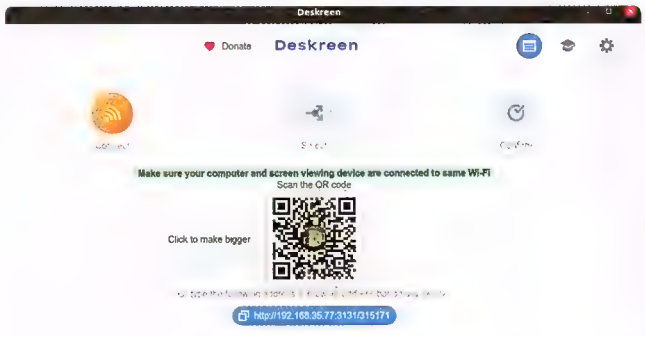
Above this are the Deskreen logo and several controls: freeze or suspend the connection using the pause button, click the settings button to flip the screen (for teleprompters) or adjust the display quality if your network bandwidth or device hardware is struggling.

Next to this is an option to view full-screen, which will remove all screen estate and maximise your remote display. While you can't interact directly with the screen you can pinch and zoom into and out of it to make things easier to read. Lastly, you'll also see a 'Default Video Player' option. This only works with your device's default browser – Chrome (Android) or Safari (iOS) – and is only required if you're using the flip-screen option.

One of Deskreen's strengths is that you can use it with multiple remote displays. Once your first connection has been set up, just click 'Connect New Device' in the main Deskreen program to set up any subsequent connections. Remember, this will require more horsepower on the part of your PC, and you'll also be constrained by the speed of your network connection.

Once set up, use the Connected Devices button at the top to review which windows are being shared with which devices, and to end any (or all) connections. For most people, the best use of Deskreen with a smaller tablet or phone screen is as a dedicated display for specific utilities that require easy monitoring, but little actual interaction. For example, you could keep an eye on resource usage in System Monitor or monitor the progress of an encoding session in Handbrake while performing other tasks. ■

HOW TO Connect your tablet or phone to Deskreen

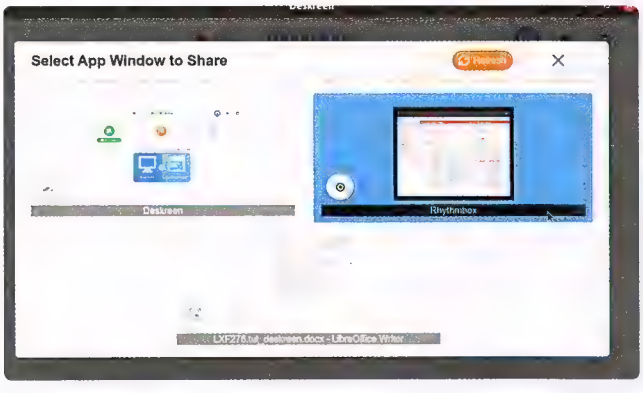


01 Scan in code or enter URL

Open Deskreen, which should display the Connect page, which will display a QR code and web address. You can either scan the QR code in using a QR code app on your tablet or mobile (in which case, it'll prompt you to click a link), or type the link directly into your mobile's browser. One of these options is significantly faster than the other.

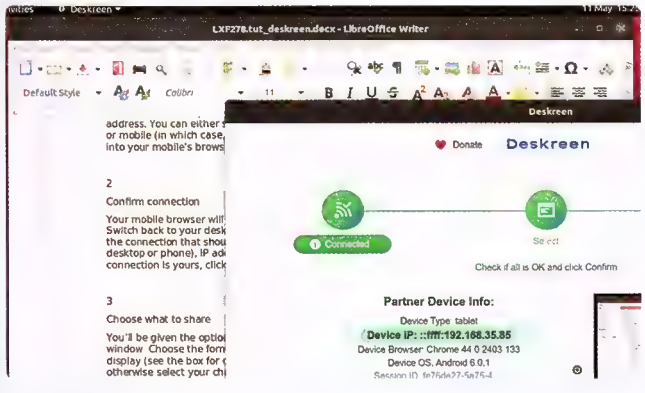
02 Confirm connection

Your mobile browser will tell you it's waiting for you to click 'Allow in Deskreen'. Switch back to your desktop, where you'll see it's displaying information about the connection that should tally with your device, namely its type (tablet, desktop or phone), IP address, browser and OS. Once you've verified the connection, click Allow.



03 Choose what to share

You'll be given the option of sharing your entire screen or a single application window. Choose the former and you'll be given the option of mirroring your display (see the box for details on using Deskreen to extend your desktop); otherwise select your chosen app window using the thumbnails as a guide.



04 Confirm and share

Review the partner device and screen or app being shared – click Confirm if you're happy, or 'No, I need to share other thing' if you chose the wrong option. After clicking Confirm, you'll see a confirmation message. Switch to your mobile where – after a short pause – the app or desktop should appear.

RASPBERRY PI

Back up and clone your Raspberry Pi

From disk cloning to backing up specific directories and partitions, keeping your Pi backed up saves time and heartache, says Christian Cawley.

While it's a flexible, affordable and much-loved piece of computing hardware, the Raspberry Pi isn't without its problems. One particular bugbear is the device's reliance on flash storage – potentially unreliable SD and microSD cards that are prone to data corruption following an unscheduled shutdown or restart.

One way to avoid this is to ensure that the Pi is shut down carefully. But it also pays to have a backup of your data, just in case the worst happens. Raspberry Pi has several options for backup, from cloning the microSD card to remotely backing up over SSH.

Clone wars

The ability to switch Raspberry Pi projects simply by swapping microSD cards means that if a card is found to be corrupt, you can easily flash an image of its contents to a replacement. Cloning the SD card is a smart option that enables you to keep a library of ready-to-use Raspberry Pi images on your PC's hard drive, ready for deployment.

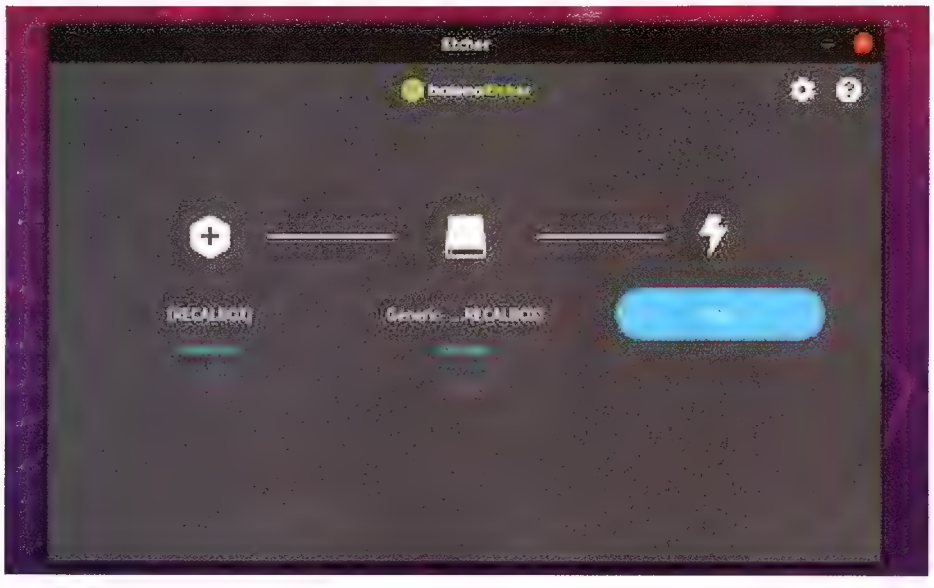
Just think of the time you can save. All your favourite software installed just once. Wi-Fi networks already configured. SSH enabled, ready to use. Where once you would reinstall and reinstall, changing numerous settings to get things just right, cloning the SD card means that you can customise Raspberry Pi OS, get things working how you like them, and then make a copy to use over and over again.

This approach isn't without its shortcomings, however. For a start, there's the volume of storage space required for multiple images. You should also consider the amount of time required for the initial image creation. Simply having a clone of a fresh Raspberry Pi OS install is pointless, because that's essentially what you can download from **raspberrypi.org**. Instead, the image should be the underlying operating system together with the key software that you want to use, along with the data you've saved to the device.

Some challenges might be faced with cloning your Raspberry Pi. For example, a 16GB disk image can't be cloned and then written to an 8GB SD card. However, you may also run into problems cloning a 16GB image to another 16GB SD card, because of differences in quality-control standards.

There may also be some difficulty booting a cloned disk image on a different system. For example, a backup that's been created on a Raspberry Pi 4 will almost certainly not work on the Raspberry Pi Zero. However, if you keep in mind basic issues of compatibility and file size, then cloning your Raspberry Pi for back-up purposes should be plain sailing. Cloning the SD card can be done on a desktop PC or on a Raspberry Pi.

QUICK TIP
Use the fastest rated microSD cards for your Pi, with A1 performance. This will ensure fast, reliable system cloning, which will help when it comes to writing a fresh disk image. Also, avoid unknown brands and stick to well-known names: SanDisk, Kingston and Samsung, say.



Rather than fiddle around with the dd command in the terminal, you can clone Raspberry Pi SD cards with Etcher.

The clone heads

To create a clone of your Pi's SD card on a desktop computer, all you need is the cross-platform flashing tool, balenaEtcher (**www.balena.io/etcher**). Download and install this on your desktop system and then insert the Pi's microSD card into the PC's reader.

You should also have a second microSD card connected ready to write to. Failing this, a USB flash stick. Writing to a system drive isn't possible without first creating a dedicated partition.

Click Clone drive and select a Source. Click Select, then Select target to choose the target drive. This should be the second microSD card. Once again, click Select to confirm, then Flash to commence. Wait while the software writes and verifies the data. You'll notice that it's possible to flash the data to multiple devices if you need to. You can also clone the Pi's SD card directly to your HDD. This is useful if you only have one SD card but plan to run multiple Raspberry Pi projects.

With the SD card inserted in your desktop computer, open the terminal, and enter the following:

```
sudo fdisk -l
```

Identify the SD card and make

a note of its name. This can be tricky, but it should be obvious from the size of the SD card. It will typically be sda or sdb followed by a number.

Next, use the `dd` command to create a clone. You can name the target file however you like, but it should have the .img extension:

```
sudo dd if=/dev/sdb of=~/raspberry_pi_clone.img
```

Wait as the process completes. When you're ready to write the disk image to a new microSD card, insert a fresh card and enter the following:

```
sudo dd if=~/raspberry_pi_clone.img of=/dev/sdb
```

You might also use the Raspberry Pi Imager tool, the mouse-driven Raspberry Pi disk imaging software available from raspberrypi.org (**http://bit.ly/LXF287-piimager**) for Ubuntu, macOS, and Windows. After installing the program, click Choose OS, then scroll to Use Custom and browse for the cloned .img file before writing it to a fresh SD card.

Clone your home

For a simpler approach that's less time-intensive, archive the Pi's Home folder. This method enables you to browse and then restore directories and files to a reimaged Raspberry Pi as and when required. Open a terminal and enter:

```
cd /home/
sudo tar czf pi_home.tar.gz pi
```

With the archive created, copy pi_home.tar.gz to another device for safekeeping. The next time you need to reimage a microSD card, once complete simply unzip the /home/ directory and copy the files you need to the Raspberry Pi.

Network backup

If you prefer using the Raspberry Pi remotely and have SSH enabled, then it's possible to back up the Pi across your network.

This isn't ideal for backing up the entire SD card, however. Some files that are in use while the Raspberry Pi is running won't be correctly cloned, leaving you with a disk image that may not boot correctly. The best option with this network approach is to back up only vital data, such as the home directory.

Begin by starting an SSH session and connecting to the Raspberry Pi. Then enter the command:

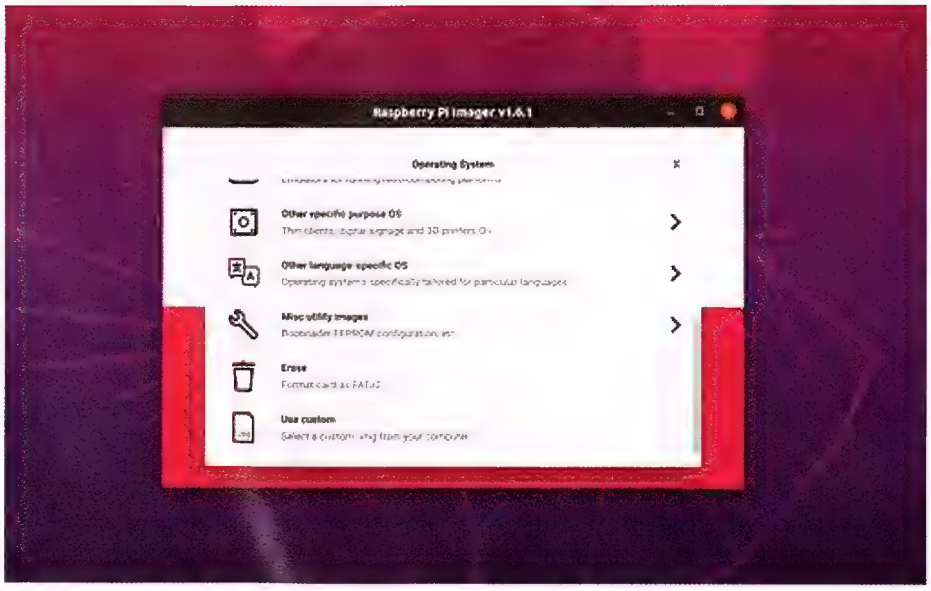
```
ssh pi@[IP_ADDRESS] "sudo dd if=/dev/mmcblk0 bs=4M | gzip –" | dd of=~/Desktop/[BACKUP_NAME].gz
```

Be sure to replace `[IP_ADDRESS]` and `[BACKUP_NAME]` as appropriate.

Wait while the backup completes. Of course, the backup cannot be restored across the network. The Pi would lose connectivity part-way through. To restore the disk image, you would need to insert the blank SD card into your computer's card reader and then use the `dd of` command:

```
gzip -dc ~/Desktop/[BACKUP_ NAME].gz | sudo dd of=/dev/rdisk1 bs=4M conv=noerror,sync
```

Remote backups using SSH will save time and wear and tear on the Pi's SD card. It's also a useful option if you run multiple Raspberry Pis.



The Raspberry Pi Imager tool has various hidden features. Among them is the ability to write any IMG file to a microSD card.

When in clone...

Backing up your Raspberry Pi files through cloning can take up quite a bit of disk space, especially if you're making regular disk images. By default, the disk images are the exact same size as the disks, rather than the data used. So, an 8GB cloned SD card would take up 8GB of hard disk space. Fortunately, the files can be compressed. All you need to do is pipe the output from dd to gzip to create a compressed .gzip file.

```
sudo dd bs=4M if=/dev/sdb | gzip > raspberry_pi_clone.img.gz
```

To restore:

```
gunzip --stdout raspberry_pi_clone.img.gz | sudo dd bs=4M of=/dev/sdb
```

The cloned file is smaller using this technique and will take up less space on your HDD. This, of course, means you can make even more Pi backups... ■

JUST BACK UP THE CONFIG FILE

If your Raspberry Pi setup is unusual, perhaps due to the hardware you've connected to the device, but you don't feel the need to regularly back up, there is an alternative. Instead of backing up the full SD card, or even archiving the /home directory, why not simply make a copy of config.txt? Existing in place of a system BIOS, config.txt stores various system parameters required for the correct running of the Raspberry Pi. Every Raspberry Pi operating system features a config.txt file, which is read by the system's GPU as the device boots.

While the Raspberry Pi is running, config.txt can only be edited as root. You'll find it in the /boot directory as /boot/config.txt. With the microSD card inserted in other systems, config.txt can be edited using a standard text editor. A whole bunch of options can be stipulated in config.txt. It enables the use of options for every possibility, from RAM use to camera settings, display options, overclocking, GPIO, and much more. For example, if you used a Raspberry Pi Zero with a small display, you would need to make some changes to the default options in config.txt. By backing up the file after the changes are saved, you can save time after a reinstallation by simply replacing the default config.txt.

CODING

Micro:bit Part 2 – Coding using your phone or tablet

Don't have a PC to code your micro:bit? Try your phone or tablet. Darren Yates looks at how to code a micro:bit board via Bluetooth using just your Android device and the free micro:bit app.

The micro:bit single-board computer is one of the best low-cost ways to help kids young and old learn the basics of computer science. With its fun mix of built-in sensors and processor powerful enough to handle the Python coding language, it gets computer programming out of the abstract and into the practical for under $30. But what if you or your classroom doesn't have a PC or laptop? No worries – just pull out your Android phone or tablet instead, download the free micro:bit app developed by Samsung from Google Play and start coding on your mobile device. You can even flash your code to the micro:bit board wirelessly using Bluetooth.

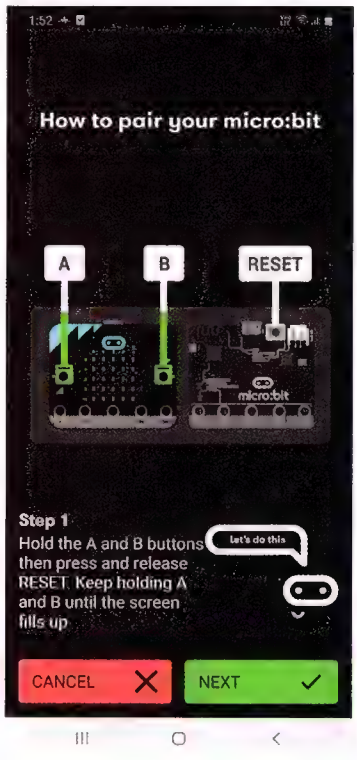
Pairing up

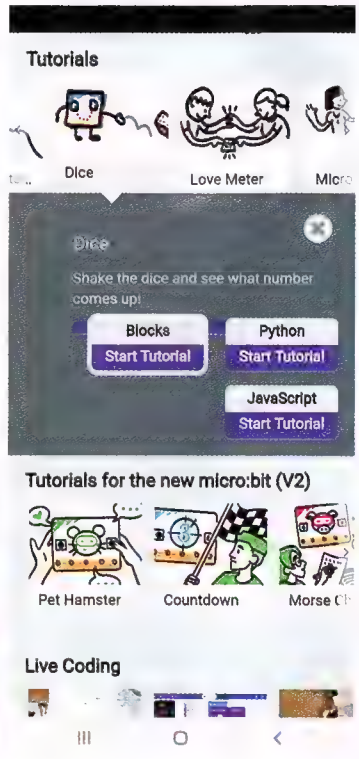
You just need an Android device with Bluetooth, internet access and at least Android 5.0. Grab the micro:bit app from **https://play.google.com/store/apps/details?id=com.samsung.microbit**, plug your micro:bit board into a power source (battery pack or USB) and fire up the app. Now to be fair, reviews suggest the app is a bit 'hit and miss' with a number of users having trouble with this next task, though the latest version as of August 2021 worked for us.

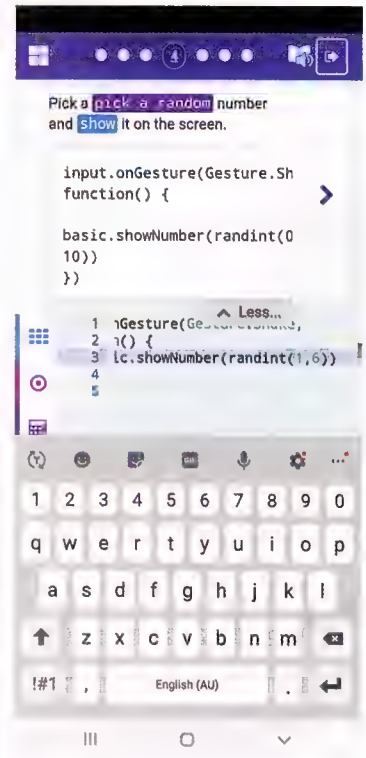
To code the micro:bit board using your mobile device, you need to establish a Bluetooth connection between them or 'pair' them. Tap on the app's 'Pair' button and on the new screen, tap the 'Pair a new micro:bit' button at the bottom. If you're asked to allow the app to turn on your device's Bluetooth adapter, do so. The next screen gives instructions on how to setup your micro:bit board – and that's hold the 'A' and 'B' buttons down (the buttons either side of the 5x5-LED grid) and at the same time press and release the reset button on the back. The LED grid will slowly fill up and reveal the Bluetooth 'B' logo. After that, it produces what looks like a weird 'pitchfork' pattern on the LED grid – that pattern is the pairing code. Enter that code on the next app screen and press the green 'pair' button. All going well, you should see the 'you have successfully paired' screen. Back out to the main screen when you're done.

Writing code

Now we're ready to code. On the main app screen, tap 'Create Code' and you'll be taken to the Microsoft MakeCode interface, which is essentially the same as the web version we looked at last month. Here, you can jump into a series of tutorials ranging from beginners through to advanced. For this month, we selected the 'Dice' tutorial, which allows you


How to pair your micro:bit
A
B
RESET
Step 1
Hold the A and B buttons then press and release RESET. Keep holding A and B until the screen fills up
CANCEL
NEXT




Pick a pick a random number and Show it on the screen.
input.onGesture(Gesture.Sh
function() {
basic.showNumber(randint(0
10))
})
Less...
1 2 3 4 5 6 7 8 9 0
q w e r t y u i o p
a s d f g h j k l
z x c v b n m
English (AU)

Far Left: The micro:bit app gives instructions on setting the board for Bluetooth-pairing. **Left:** The Microsoft MakeCode section provides lots of tutorials to get stuck into. **Right:** You can code the micro:bit board straight from your phone.

to code your micro:bit into a simple six-sided dice – shake the board and it'll give you a new random result between 1 and 6. The MakeCode tutorials give you the chance to code in Blocks, Python or JavaScript – just tap the icon for the language you want to try.

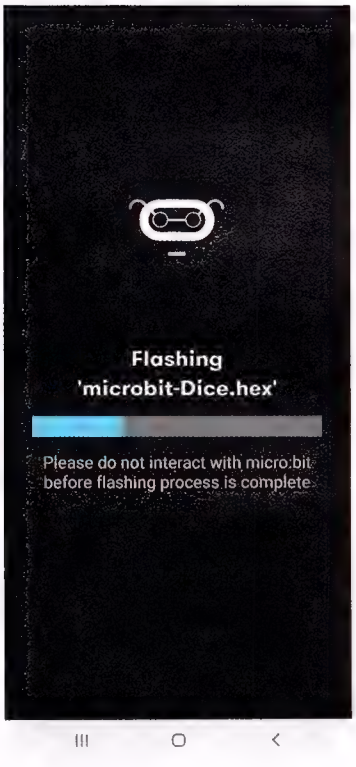
The tutorials are easy to follow and give you the answers as you go – you just enter in the code in the code editor window. To show just how efficient micro:bit coding is, the 'Dice' tutorial requires barely four lines of JavaScript code:

```
input.onGesture(Gesture.Shake,
function() {
    basic.showNumber(randint(1,6))
})
```

It basically says that when the board's input (in this case, the accelerometer sensor) receives a 'gesture' (in this case, a shake), run the code inside the 'function()' block, which is show a random number between 1 and 6 on the LED grid. While the app's on-screen coding editor does work, we think the user interface could use some tweaking for phone screen-use, particular the placement of controls and improving the text proportions.

Flashing your code to micro:bit

Now your code is written, you compile it online and download



Once your code is done, flash it to the micro:bit board via Bluetooth.

The micro:bit V2 Go kit includes board, battery pack and cable for under $30.

or 'flash' it to your micro:bit board. Do this by pressing the purple 'download' icon on the bottom-left of the app screen (it's the document icon with a down arrow on it). If you have trouble, here's a tip – trying putting the micro:bit into Bluetooth mode again by holding down the 'A' and 'B' buttons and pressing and releasing the reset button. This helped us on a couple of occasions.

While the Android app gives you a flash progress bar, it'll be mirrored on the micro:bit board's LED grid. Once complete, it'll run your code. If so, congrats – you can now code your micro:bit board wirelessly using your mobile device.

Learning computer science

Typing in 'software developer' into job site Seek on August 1 returned over 6,800 available roles. However, look at any of the roles and you're usually required to know more than one programming language – often many more than one. One of micro:bit's really useful features is the option to code in Python or JavaScript, which just so happen to be two of the top-five coding languages worldwide. But if learning one language seems daunting, the idea of learning more than one will often scare potential coders away.

When you learn to code, you're actually learning two things – you're learning the makeup or 'syntax' of a particular language, but you're also learning how coding works. You're gaining knowledge in how the logic of programming fits together, part of what's often called 'computer science'. The key is if you can understand this logic or theory of programming, you can start seeing the parallels between different programming languages.

I'll give you a quick example here using the micro:bit 'dice' tutorial we mentioned before. Here's the JavaScript code again:

```
input.onGesture(Gesture.Shake,
function() {
            basic.
showNumber(randint(1,6))
})
```

and here's the Python version:

```
def on_gesture_shake():
    basic.show_number(randint(1,6))
input.on_gesture(Gesture.SHAKE, on_
gesture_shake)
```

Aside from indenting being mandatory in Python, you can see the similarities between the two. Both have a function – function() in JavaScript and the 'def' block in Python. Both have a 'shownumber'-style command where the input is a random whole-number between 1 and 6. Both have an input function that activates on receiving a 'shake' gesture. Now, yes, this is a simple example and there are more differences between these two languages when you delve deeper, but they're often more about syntax and less about coding logic.

Give it a go

Learning to code takes work but is so worthwhile – not only does it open up new employment opportunities, but it also opens up a world of enjoyment in learning to build your own tech. Over the years, we've built everything from robots to encryption machines to digital audio recorders using low-cost microcontroller boards. The limit is your imagination. We'll finish off our series next month with a look at the vitally important world of sensors. See you then. ■

DOWNTIME

INSIDE THE GAMES GAME

AMIGA 500 MINI PACKS 25 GAMES INTO A TINY FRAME

A PC classic gets the mini-console treatment.

Retro Games Ltd has announced the Amiga 500 Mini, a small Amiga emulation box that works similarly to the recent Commodore 64 Mini. No measurements have been released as yet, but it'll likely be about a quarter of the size of the original – save the bundled mouse and gamepad, which are both the same size as the originals.

As always with these retro systems, this is an aesthetically pleasing keepsake rather than an optimal way to emulate Amiga games. It comes with 25 in-built titles, including *Another World*, *Battle Chess* and *Worms: The Director's Cut*, but you can also side-load any Amiga games you already own via a USB stick. There's also save and resume functionality, a selection of scaling options, and a CRT filter that will hopefully ape the style of ye olde monitors.

BACK 4 BLOOD SOUND EFFECT THAT RESEMBLED A RACIAL SLUR WILL BE REMOVED

The unfortunate undead bark was the product of audio randomisation.

Last month's *Back 4 Blood* beta was mostly well-received, with the exception of one unusual drawback: the roaming undead could sometimes be heard shouting what sounded extremely similar to a racial slur.

Twitter user HomBKE was apparently the first to bring it up, but other footage followed and, yep, it definitely sounded like the n-word. When the n-word is noticed in your game, it would be remiss not to address it. Turtle Rock issued a statement on the matter shortly after footage emerged, assuring that it wasn't intentional. "There is a known beta issue where several ridden growl sound effects are randomly combined by the system in such a way to create what sounds like an offensive slur," the official *Back 4 Blood* Twitter account tweeted. "While unintentional, we take this very seriously and are profoundly sorry for any hurt or harm this may have caused. This issue will be fixed prior to launch."

Valve fixes Steam bug that allowed unlimited wallet funds

Though it doesn't sound like anyone exploited it.

If you're feeling a bit evil, it might come as bad news that Valve has eliminated a Steam bug that allowed users to greatly amplify deposits placed in their store wallets. It worked like this: the user would deposit an amount into their wallet, change their account email address to something including the text "amount100" and then do some light code manipulation to confuse the interaction between Valve and its third-party payment system Smart2Pay. In this way, the user could – for example – change a $1 deposit into a $100 one, or a $10,000 one.

The hack was discovered by a white hat hacker known as drbrix, who, being a white hat hacker, opted to submit the problem to Valve and gather a bounty, rather than distribute the information online.

Epic Games Store is throwing money away to dominate Steam

The company has already spent US$500 million.

Epic Games and Apple are still in court over *Fortnite*, and the court proceedings continue to throw up some interesting details that would otherwise be out of bounds. Like this one: according to Apple's lawyers (who are excellent at requesting and winning subpoenas), "Epic lost around US$181 million on EGS in 2019. Epic projected to lose around US$273 million on EGS in 2020. Indeed, Epic committed US$444 million in minimum guarantees for 2020 alone, while projecting, even with 'significant' growth, only US$401 million in revenue for that year."

Apple's lawyers brought it up to demonstrate the difference between Apple's extremely profitable App Store and Epic's (unprofitable) one. Probably an unfair comparison – Apple wasn't fighting against a monopoly like Epic is – but Epic is determined: it's paid out at least US$444 million on "minimum guarantees" to game developers and publishers for exclusivity on the Epic storefront, not to mention what it's paying for its regular free game giveaways, such as *Control* (which the company paid US$10.45 million for).

But they probably don't need to worry too much: *Fortnite* is still raking in gold, and Unreal Engine 5 is on the horizon.

PSVR PS5 headset sounds "even better" with supposedly leaked specs

Digital Foundry has apparently heard details of the upcoming headset.

The PSVR PS5 headset could be "even better" than previously rumoured, according to one outlet. That outlet would be Digital Foundry, tech experts who just recently posted the new "Digital Foundry Weekly" episode to their YouTube channel. In the new episode, host and tech expert Richard Leadbetter says that "we've seen some leaked PSVR PS5 specs and it looks good," before adding "we've seen some other specs which haven't been leaked which make it look even better."

We don't know the specifics of these as-yet-unseen specs doing the rounds about the PSVR PS5 headset, nor do we know which previous leaked Leadbetter is referring to. Earlier this year in June, you might remember one report claimed that the new headset from PlayStation would utilise OLED screens, which Sony has never commented on.

Slightly before that in May, another outlet reported that the new headset would feature 4K visuals, gaze tracking, and rumble functions. Again, this report was never confirmed or denied by PlayStation.

R2-D2 TAMAGOTCHI IS COMING IN NOVEMBER AND IT'S CUTE AS HECK

A new post on the official *Star Wars* site reveals the new virtual pet toy based on everybody's favourite Astromech droid is coming to stores on November 11, with the Amazon listing revealing a planned price of US$19.99 (and yes, you can pre-order right now if you already know you're going to want one).

THE RAMP IS A CHILL SKATEBOARDING GAME THAT GIVES YOU HALF-PIPE ASMR

It hit Steam recently for US$4.99, and as developer Paul Schnepf explains, it was built to "scratch a very specific itch, which was capturing the incredible flow of half-pipe skateboarding." At its core is a pumping mechanic which encourages you to stay in rhythm.

FORMER ELDER SCROLLS DEVS REVEAL THE WAYWARD REALMS, A NEW FANTASY RPG "ON A SCALE NEVER ATTEMPTED"

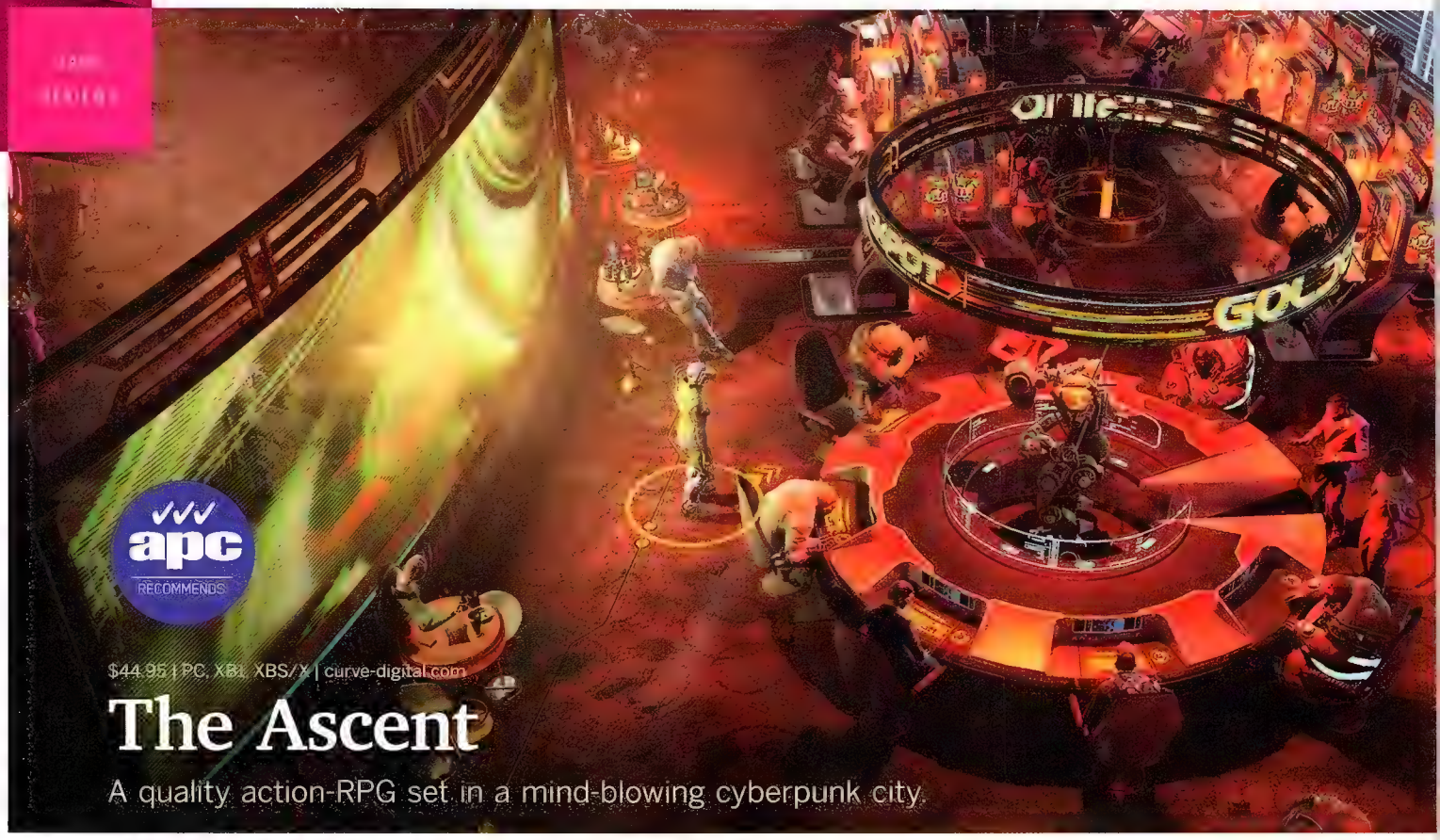
How big? Positively grand.

The Wayward Realms is a highly ambitious new open-world fantasy RPG from a pair of veteran *Elder Scrolls* developers.

Back in 2019, *The Elder Scrolls Arena* and *Daggerfall* leads Julian LeFay and Ted Peterson announced their new studio OnceLost Games and said they were working on a big new RPG. Now we have the first teaser trailer for the game, as well as a few screenshots and a beefy description via its new Steam page.

Reading again how OnceLost Games describes *The Wayward Realms*, "highly ambitious" might actually be an understatement; the developers call it "a new open-world fantasy RPG where choice and consequence are experienced on a scale never attempted before." They even have a fancy new term for the type of game they're making: The Grand RPG.

The official description also says *The Wayward Realms*' map is "way bigger than most other games you can think of" and houses hundreds, if not thousands of NPCs, as well as "deep, dark, dangerous forests, gigantic mountain ranges, sprawling swamps and marshlands, vast oceans, and more." ■



apc RECOMMENDS

$44.95 | PC, XBL XBS/X | curve-digital.com

The Ascent

A quality action-RPG set in a mind-blowing cyberpunk city

Along with thousands of other galactic migrants, your character in *The Ascent* pays a small fortune for a ticket to the planet Veles, looking for a better life. The moment you step off the ship, however, the price of the ticket becomes a debt so astronomical that you'll immediately be burdened with working dirty, dangerous jobs to pay it off.

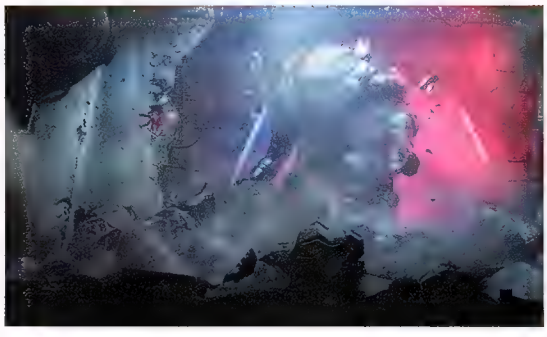
The Ascent's setting, a mix of neon-flecked '80s cyberpunk and grimy science fiction, is magnificent. The story takes place in an Arcology – a self-contained city squeezed into an immense skyscraper. Think Hong Kong's Kowloon Walled City, crossed with *Akira*'s Neo Tokyo, and populated by the aliens from the Mos Eisley cantina. It's an urban crush of markets, plazas, and concrete valleys buzzing with streams of flying cars. It's a hell of a setting, and one of the most compelling cyberpunk worlds on PC.

The Ascent is an action-RPG, with an emphasis on the action, that you can play alone or with up to three friends in co-op. It's a gloriously chunky, brutal isometric shooter where you run around that gorgeous city blowing enemies away with shotguns and churning them into a fine bloody mist with rattly machine-guns. Loot, money, and power-ups sprinkle out of their corpses, and scooping these up provides a constant stream of tiny, pleasing dopamine hits.

The relentless rhythm of *The Ascent*'s combat forces you to be in near-constant motion. Gun-toting enemies are accompanied by large groups of melee grunts. They push forward aggressively, never giving you a chance to get settled or get too comfortable behind cover. When you begin the game, your lowly indent is working a job in the Deepstink, the lowest part of the city. But as you make a name for yourself, working as a mercenary for an influential crime boss, you find yourself rising to the top – literally.

The story takes you from the stinking depths of the Arcology to increasingly higher, more opulent levels, all of which have a very different aesthetic and vibe. This is fundamentally a game about shooting lots of people dead, including gangsters, corporate soldiers, and hulking mechs. But there are some quiet moments too. In crowded social hubs you can shop, talk to NPCs, and pick up sidequests without fear of being attacked.

On the rare occasions the game does something to disappoint me, the world always wins me back. From the lavish Golden Satori casino to the bleak Black Lake slums, this is a masterclass in creating a sense of place. *The Ascent* is a superb shooter elevated by a great setting.



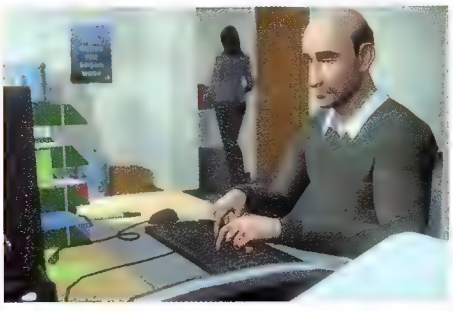
Top: It plays in 3rd-person, though a 1st person mod can be applied if you prefer. **Above:** An evocative and compelling world.

The Ascent nails the grimey lived-in look much better than *Cyberpunk 2077* managed.

A lovingly crafted action-RPG with satisfying gunfights and an exceptional cyberpunk setting. **Andy Kelly**

★★★★☆

Remember commuting? Relive the excitement in *Last Stop*.



\$35.95 | PC, XB1, XBS/X, PS4, PS5, Switch | variablestate.com

Last Stop

Four Londoners are about to have a very bad day in narrative adventure.

Last Stop is a game about extraordinary things happening to ordinary people. Set on the streets of London, it follows four very different characters whose unremarkable lives are suddenly touched by the supernatural. It's an offbeat mix of the mundane and the fantastic, where one minute you're making a cup of tea, and the next you're tumbling through a portal into another dimension.

Last Stop is a linear narrative game. You tell the characters what to say in conversations, occasionally move them through heavily choreographed scenes, and not much else. In this sense, as a game, it's very limited in scope. It has the feel of an anthology, telling three loosely linked stories that eventually intersect in the final chapter.

When the three stories finally collide, *Last Stop* shifts in tone so sharply you'll wonder if you're playing the same game. The wild final chapter is an enjoyable, unexpected ending for sure, but so outlandish that I couldn't help but feel that it slightly cheapened the nuanced, heartfelt drama leading up to it.

I just wish there was more to it. The QTE-style interactions feel clumsy, and I never got the sense that I was actually controlling the characters. There's no tactile feeling to the interactions, whether you're tapping the bumpers to sprint or rotating a stick to stir a mug of tea.

Last Stop is one of the least satisfying narrative games I've played recently in terms of the mechanics underpinning everything. It's really basic stuff, even compared to early Telltale games, where you at least got the chance to snuffle around the environments for extra flavour. But everything else – the engaging plot, the stylish presentation, the sublime orchestral score – are all superb.

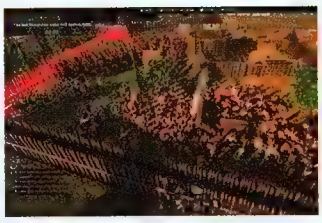
If you're happy just to be told an entertaining, if not entirely interactive, story in a realistic depiction of contemporary London, with a little spooky magic sprinkled in, there's a lot here to love. Just brace yourself for that ending.

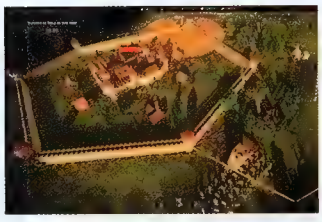
A smart, funny, heartfelt narrative game that tells a killer story, but doesn't do much beyond that.

Andy Kelly

★★★☆☆

Above left: Despite its mundane appearance, *Last Stop* is a gripping narrative-based game. **Above:** Ordinary people, ordinary lives...





Free | PC | bit.ly/VedelemGame

VEDELEM: THE GOLDEN HORDE

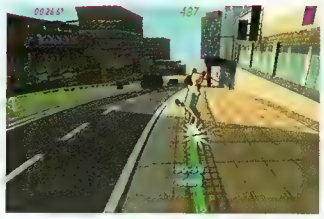
Building frantic defences.

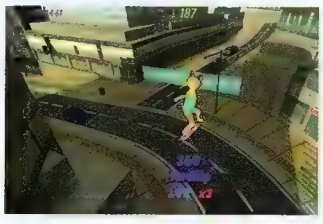
Vedelem is a strategy game where you're trying to defend a fragile central keep, primarily by building walls and training squads of eager little soldiers. When the enemy arrives – they appear in waves over the course of each game session – you drag-select and inflict your troops upon them, in the tried and tested RTS manner. It's pretty satisfying, zooming in to watch them wail on each other, despite the budget, slightly wonky animations. In the late game, the number of soldiers can get ridiculous.

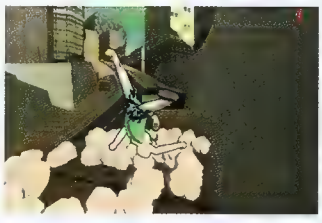
Walls will help slow down the invaders, while swordsmen, archers and spearmen will obviously mop them up – but everything comes back to those resources sitting on the procedurally generated map. While you're fighting, you should also be building stuff: sawmills to harvest wood, houses to gather villagers, quarries to break up useful stone. Naturally, each building can be upgraded, as can your keep, soldiers... well, everything. Fans of city builders will be at home laying everything down and watching the resources roll in. It's just a shame there are no little villagers ferrying the goods back and forth.

An impressive RTS that makes up for its rough edges with satisfying strategy. **Tom Sykes**

★★★½☆







Free | PC | kabutokai.itch.io

DOWNHILL JAM

It's all downhill from here.

Downhill Jam comes remarkably close to the legendary *Jet Set Radio*, offering a downhill course in a similarly funky city. There are little alternate routes, collectible cash, and at the end a score so you can see how badly you did.

In *Downhill Jam* you're a cat on a hoverboard. You can customise the cat, giving it a hat and different boards to ride. But, despite the hovering, it feels familiarly like a skateboard, grinding rails in the same way and with controls that have become the standard over the years.

That's *Downhill*'s greatest strength: you can pick it up and (probably) know how to play it, grinning as you attempt its course a couple of times. The university students behind it have used their project time to make a small, polished game, rather than a broader and potentially scrappier one. Given that so much of skating is about the feel of it, I think that was the right approach.

Captures the sensation of skating, in a world that largely looks the part. **Tom Sykes**

★★★★☆

Above: The atmosphere is grimly dank. **Above roght:** Dressed for the occasion.

$43.95 | PC, XB1, XBS/X, PS5, Switch | chernobylgame.com

Chernobylite

A rare game that makes you feel the weight of your decisions.

Chernobylite is a curious mash-up of ideas orbiting around a pretty stiff first-person shooter framework. But it feels more inviting thanks to its evocative setting and cast of grizzled scavengers. Despite some shortcomings, it succeeds as a game about choice, where you're constantly faced with quandaries that may meaningfully affect the hero Igor's journey as he chases spectral visions of his wife around the Chernobyl Exclusion Zone.

Killing a sketchy character early on might lead to an awkward impasse with his wife later, split-second decisions about whether or not to save stalkers from patrolling army guards will dictate how many allies and enemies you have in the Zone, and at every key point you'll have companions radioing in to persuade you to do stuff. Each time you die, you wake up in a dreamscape where you can see how the key decisions you made are connected, and go back and change those decisions using mysterious *Chernobylite* shards as payment to whatever interdimensional god-force is running the show.

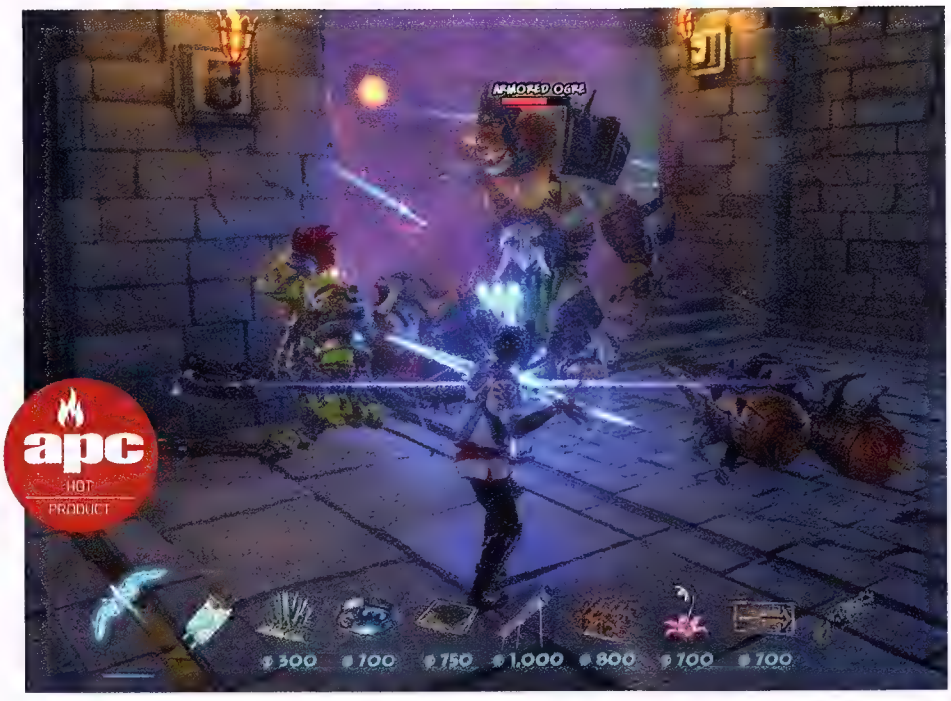
Between missions you hang out in your base, where you can cook, build improvements, explore other peoples' memories based on clues you find, or even just go straight to the Heist mission at the end of the game. When you're ready, you pick a mission set in one of six regions around the Zone – where you can progress the main story or search for clues. At the same time, you can send out your companions to scout future missions or gather resources.

What really gives *Chernobylite* its soul are the people you recruit to your base. There are five in total, each with their traumas, missions, and stories to tell.

Chernobylite's greatest strengths aren't easily conveyed through trailers or genre tags. Its cast of characters and its choice system are genuinely gripping, while its depiction of the Zone is at times breathtaking. Like its motley crew of mad companions, *Chernobylite* is a misfit that I can't help but like.

An ambitious and atmospheric adventure undercut by some simplistic mechanics. **Robert Zak**

★★★★☆



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Orcs Must Die! 3

Action tower defence comes home.

This isn't a thoughtful fantasy game: it makes little effort to contextualise its maligned title characters, to ponder where they come from or why they do what they do. Yet it is a thinking person's game – a strategic siege simulator that rewards careful arrangement, inspired solutions, and a willingness to toss away past assumptions and approach a problem from a new angle. It's a game that makes you feel smart, even as you swing your mouse desperately to slug an imp in the eye with a bolt of magic.

Imagine you're an interior designer, but in a universe where one of the tenets of feng shui is murder. Using a budget, you begin each level by buying, rotating, and placing the traps of your choice in a small dungeon with the aim of causing as much damage as possible to any orcs who might pass through.

Then it's open house: the doors smash inward, and enemies run down the hall and up the stairs, displaying a remarkably low aptitude for hazard perception as they do so. The traps they trigger come from the *Tom & Jerry* school of slapstick comedy, flipping orcs through the air or stinging them with beehives; those awaiting the upcoming *Jackass* reunion will find themselves well served.

In a traditional tower defence game, the arrival of the action phase would be your prompt to sit back, take in the scene, and grit your teeth – hoping your walls will hold, and throwing down an extra turret or two when funds allow. In *Orcs Must Die! 3*, it's the moment to roll up the sleeves of your gown and jump in.

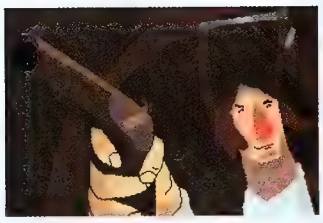
There's less complexity or opportunity for skill than you'd find in a dedicated action game, but that's for the best. If the fighting were any more involved, it would pull too much focus, upsetting the balance of this classic genre hybrid.

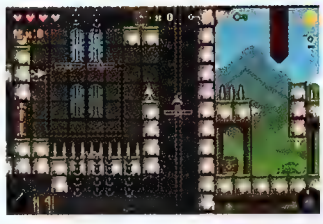
A conservative but confident return to form from the masters of a much-loved genre. **Jeremy Peel**

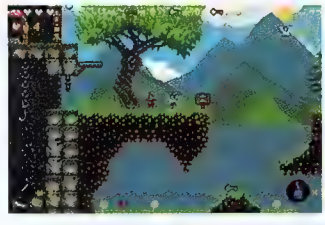
★★★★½

Orcs in the process of dying.

The traps are set... let the Orcs come forth to their doom.







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JANOSIK

Robbing the rich in a retro platformer.

They don't make platformers like they used to – and that's mostly for the best. I have a hard time going back to games on the Mega Drive; there's not a lot of humour, or playfulness, now that everything's an emotive *Metroidvania*.

Janosik is a *Metroidvania*. You'll unlock abilities including a double-jump, and double-back on yourself. But it's one with the spirit and energy of an Amiga game. There's a boisterous chiptune soundtrack and vivid pixel art, but above all there's the speed of it – *Janosik* knows you lead a busy life, so it hurls you around the place at a blistering clip.

Despite being set in a large, connected world, not an inch of map is wasted here. *Janosik* is an ant farm of activity, jam-packed with secrets, spikes, and patrolling enemies. I just wish I had more skill with it, or that the checkpoints were a little more generous. As it is, I was ultimately worn down by having to repeat large sections of the game.

Sometimes you want a nostalgic shot of light-hearted platforming. **Tom Sykes**

★★★½☆

Subject Delta is a powerhouse in combat.

GAME CHANGER

Bioshock 2

Andy Kelly revisits BioShock's bold, brilliant sequel.

RELEASE 2010 **DEVELOPER** 2K Marin **PUBLISHER** 2K Games **LINK** www.bioshockgame.com

When *BioShock 2* was released back in 2010, it had only been three years since we last got our feet wet in briny depths of Rapture. I remember feeling like the undersea dystopia was still relatively fresh in my mind, and had little desire to return. However, this sequel that nobody really wanted turned out to be confident, intelligent, and imaginative, matching the quality of the original, and in some ways bettering it. It's the story of a Big Daddy, Subject Delta, searching the decaying, leaky corridors of Rapture for his Little Sister, and butting heads with Sofia Lamb, the psychiatrist turned cult leader who betrayed him.

Rapture was in a bad way in *BioShock*, but a decade later it's in an even worse state of disrepair. Entire districts of Andrew Ryan's monument to hubris are now completely submerged in ice-cold Atlantic sea water. The once lavish ballrooms, bars, and department stores are damp and rotten, crusted with barnacles. It's a vivid depiction of a place losing a battle with nature, and a highly effective setting. Still identifiably Rapture, but grimmer, dingier, and more hopeless.

It's also more dangerous, thanks to the presence of brute splicers – grotesque ADAM-powered giants – and the Big Sisters, an agile, powerful, and terrifying new kind of protector you have to contend with. When the ocean swallows this place up, it'll be doing it a favour...

Daddy cool

Stepping into the clunky boots of a Big Daddy gives you a uniquely interesting and more intimate perspective on the city. You aren't an outsider (or someone who believes they're an outsider) like Jack in the original game, but a key part of Rapture's bizarre ecosystem. Subject Delta, a prototype model, is different from the lumbering, groaning Big Daddies who stomp around the city protecting the Little Sisters. He has rather more free will, and a special, lifelong bond with one Little Sister in particular, Eleanor. If she dies, he dies, which gives him extra motivation to track her down, beyond just gene-induced fatherly love. From a story perspective, playing as a Big Daddy is actually an inspired idea. But in terms of actually moving around Rapture, you don't really feel like one.

There's very little weight to the controls. No real sense of being a towering, heavy figure clad in an iron diving suit. Even the drill, a trademark weapon of the Big Daddies, feels curiously feeble when you swing it. The first-person controls are basically identical to Jack's in the original game, which detracts a little from the sensation of being a Big Daddy. The game might not have been much fun if you spent the whole playtime slowly clomping around the expansive city of Rapture, but just a little more weight would've helped the illusion.

The classic one-two combo, made easier.

I do like how you can hear the tap of water on your helmet when you stand under a leak, though. And occasionally, if the light hits you just right, you catch a glimpse of your hulking great shadow, which reminds you that, oh yeah, I'm a Big Daddy, aren't I?

Harvest boon

You might not move like a Big Daddy, but you do occasionally act like one. At certain points in *BioShock 2* you have to protect a Little Sister as she goes about her rounds, sucking ADAM out of splicer corpses and recycling it. This is a neat way of making you a part of a dynamic you observed countless times back in the original game. When the Little Sister begins the harvest, waves of splicers descend on her, which brings the sequel's improved combat to life. Being able to simultaneously wield a gun (or drill) in one hand and a Plasmid in the other is the most significant change, dramatically increasing the pace and aggression of battles, and letting you pull off power/weapon combos more fluidly.

Cold, calculating villain Sofia Lamb is the polar opposite of Andrew Ryan. He worshipped the ideal of the self, an objectivist, while Sofia believes in the power of the many. A communist, basically – exactly the kind of person Ryan feared might one day invade and conquer his city. She's an influential figure in Rapture, but why no mention of her in the first game? The real answer is, she hadn't been written yet. But in the game there's a hand-wave about her being imprisoned by Ryan and all traces of her teachings being hidden away from the masses. As an antagonist she doesn't have the charisma or zealous fire of Ryan, but her quiet ruthlessness does a good job of setting her apart.

One of the sequel's cleverest tricks is how your morality affects not only your own conscience, but Eleanor's story too. At several points in the game you're given the opportunity to kill or spare a character, and how these decisions play out can result in one of several different endings. If you have a callous attitude to life and death, Eleanor will notice, using you as her moral compass. But if you show compassion, she'll ultimately become a better person. This is so much more interesting than just saving or harvesting the Little Sisters in the first game, and has higher

SHOCK AND AWE *The 'Shock series so far*

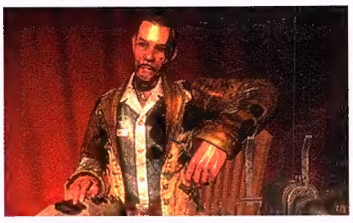
SYSTEM SHOCK
1994
This first-person cyberpunk RPG introduced the world to SHODAN, a malevolent artificial intelligence, and one of gaming's greatest villains.

SYSTEM SHOCK 2
1999
This sequel, written and designed by *BioShock* creator Ken Levine, was hugely influential, setting the standard for immersive sims.

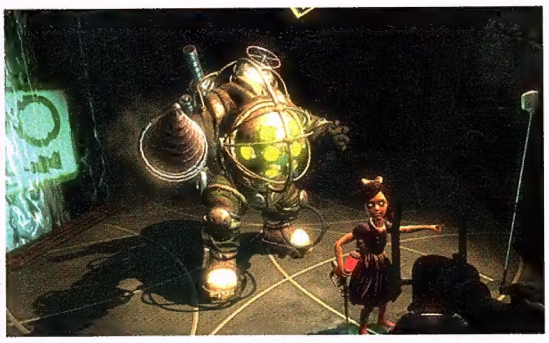
BIOSHOCK
2007
Designed as a spiritual successor to *System Shock*, *BioShock* moved the action from space in the future, to an undersea city in 1960.

BIOSHOCK 2
2010
Development of the second game was handed to 2K Marin. People initially doubted that a sequel would work, but they absolutely nailed it.

BIOSHOCK INFINITE
2013
Ken Levine returned to *BioShock* for this sequel, set on the floating city of Columbia, which ignites fierce critical debate to this day.



Ryan is dead, but his propaganda lives on.



Above: Experiencing Rapture from a different perspective is fascinating.
Right: Time to learn a bit more about the history of Rapture.
Far right: Fighting Big Daddies is still commonplace in *BioShock 2*.

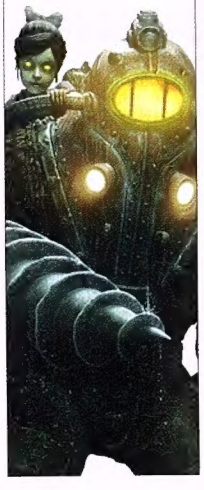
emotional stakes for the protagonist. There are multiple endings – or rather, around six variations of the two main endings – and the outcomes of each can be drastically different based on the decisions you make and, by association, the influence you have on Eleanor.

Level up

BioShock 2's level design is also a step up from the first game. The overall themes of the districts aren't quite as striking – there's nothing here to rival Fort Frolic, for example – but the maps themselves are more complex, multi-layered, and spatially imaginative. In our first trip through Rapture we saw the lives of the rich and influential, but here we get a glimpse of what it's like to be down and out in Ryan's city. Pauper's Drop, a rail maintenance facility turned slum, is the best example of this. The dense, detailed shanty town is bursting with little stories, showing an even uglier side to the city than we'd ever seen previously in the original *BioShock*.

We also get some flashes of life on the other side of the tracks, including the Adonis Luxury Resort, a spa for the wealthy and pampered. And the trip to Ryan Amusements – a propaganda theme park – is a clever way of giving Andrew Ryan and his philosophies a presence in the city, despite him being dead for many years.

"One of the sequel's cleverest tricks is how your morality affects not only your own conscience, but Eleanor's story too. At several points in the game you're given the opportunity to kill or spare a character, and how these decisions play out can result in one of several different endings."



While *BioShock 2*'s improved combat, nuanced approach to morality, and more interesting level design makes it functionally a better game than *BioShock*, I do still think that the original is the superior experience. Descending into Rapture for the first time, learning about the city and its collapse, and the big reveal at the end are difficult to beat. Returning to Rapture in *BioShock 2*, it still has impact as a setting, but that feeling of beguiling, wondrous mystery just isn't quite there. This at least makes sense in terms of the fiction. Subject Delta was created in the city and lived there for some years, which gives our familiarity with the setting as *BioShock* players some in-universe logic.

Thanks to the 2016 remastered re-release, *BioShock 2* runs perfectly on a modern gaming PC. That being said, you shouldn't expect much from the 'remaster' – it looks basically the same as it did when it was first released back in 2010. The main reason to play this version is improved compatibility with Windows 10, a 4K-friendly UI, and built-in support for modern gamepads. And you get both DLCs – *The Protector Trials* and the superb *Minerva's Den* – bundled in, making it a complete singleplayer package.

Sadly, the game's excellent, largely forgotten multiplayer mode is nowhere to be found in the re-release, and no longer possible to play in the original version. That's a real shame, but it's the singleplayer that really makes *BioShock 2* special, and it remains one of the best, and boldest, sequels ever made. ■

CHIP CHAT

JOEL BURGESS REPORTS ON THE UNUSUAL SIDE OF TECH NEWS

THE UK HAS A CRAPPY IDEA TO FIX REMOTE INTERNET CONNECTIVITY

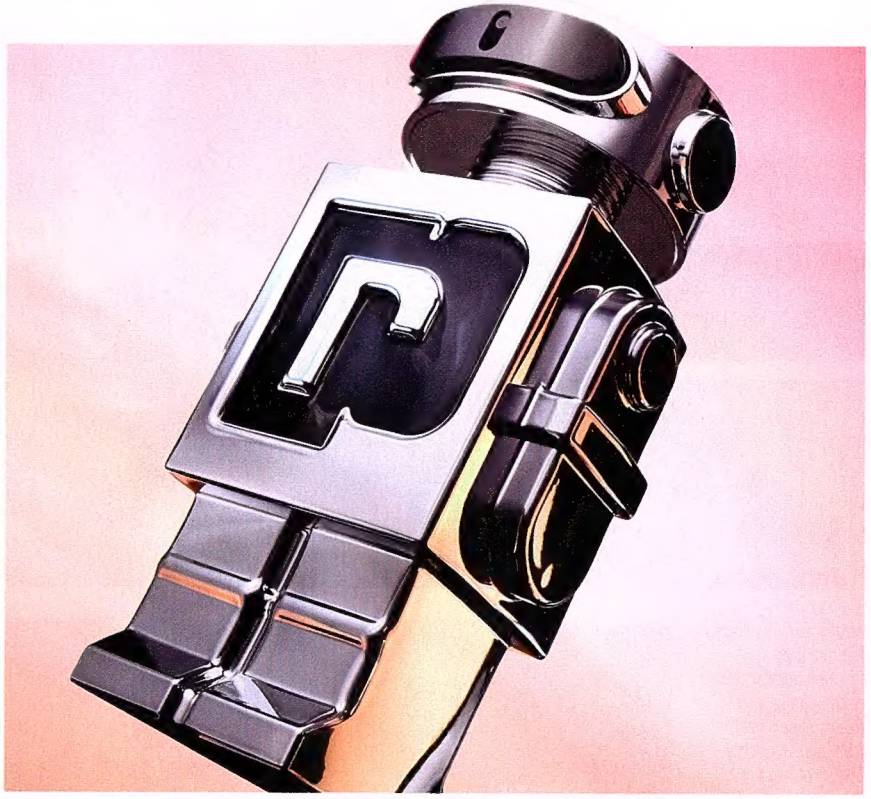
Fibre optic cable to run through shared sewage and water infrastructure in Britain.

While there's undoubtedly plenty of crap on the internet, you wouldn't normally consider that your internet line needed to be run through sewage pipes, but that's just what a new project in the UK is looking at doing. Britain is calling for commercial pitches from companies to use existing water infrastructure to deliver fibre optic cables to regions that have been deemed too remote to justify the cost of digging standalone telecom infrastructure. Broadband cables have been run in shared infrastructure across Spain already and may offer novel opportunities to detect water leaks.

ETHERROCK CLIP-ART NFT SELLS FOR $422,000

Basic royalty-free rock graphic sells for 95.2 ETH.

You've probably already been appalled by CryptoKitties or the various other exorbitant NFTs that circulate the web these days, but somehow it doesn't make the US$422,000 purchase of an EtherRock in August any less fascinating. EtherRock, according to its anonymous developer quoted in *Vice*, "was originally intended as a) a joke and b) an exercise for me to learn [the Ethereum coding language] Solidity." The dev said they would have put a lot more effort in had they known the royalty free clip-art rock NFTs would have been so popular, but according to investors like former number two at major crypto investment firm Digital Currency Group, "rocks are about flexing", so maybe it's the crappiness that's most appealing.



Paco Rabanne used AI to concoct its Phantom fragrance

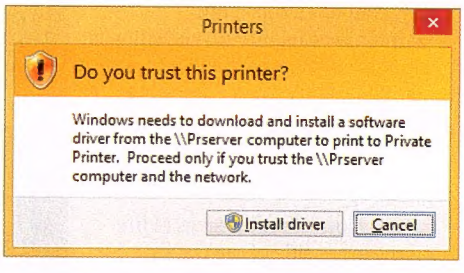
New smelly AI elixir proven to 'unlock feelings'.

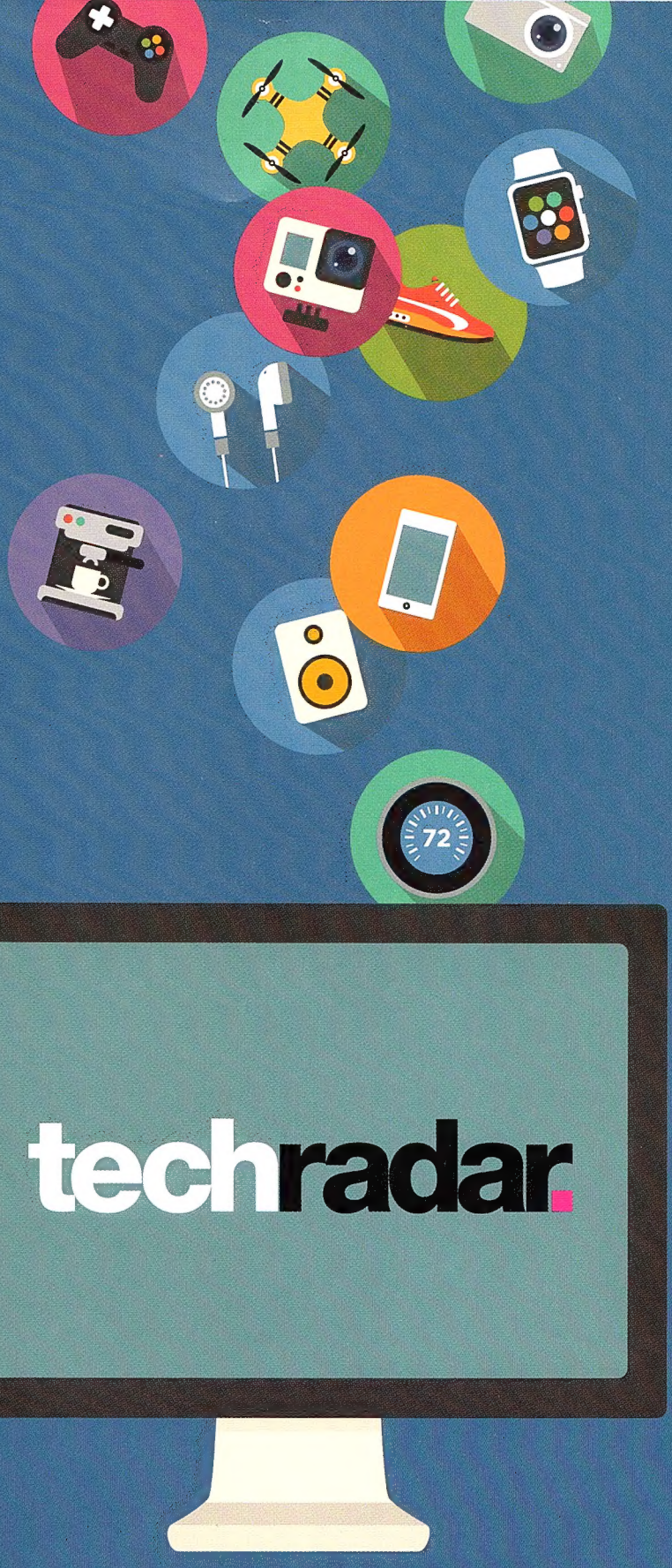
While most fragrances search for the holy grail of pheremones that'll spellbind any member of the opposite (or same) sex, a newly minted fragrance from the Paco Rabanne fashion house is designed to make the wearer have "increased feelings of sexiness and confidence", according to a company press release. The most unique feature of this novel fragrance however, is that it was concocted using a recipe dreamt up by an AI algorithm. If that wasn't enough, this supercomputer fragrance comes in a robot-shaped bottle that can connect to an app on your smartphone via an NFC chip to provide games, photo filters, playlists, and AR experiences.

WINDOWS POINT AND PRINT VULNERABILITY LEADS TO ADMIN ONLY ACCESS

A security exploit just made office printing much harder.

Printing is the kind of IT task that most of us take for granted until something goes wrong, but it's actually come a long way thanks to features like Windows Point and Print, which connects you to web-hosted drivers for printers that you haven't used before. In August however, Microsoft thrust printers back into the dark ages by removing the ability of standard Windows users to install or update these printer drivers. In order to fix a demonstrated exploit of Point and Print for large corporations that was discovered by an engineer from Dark Wolf Solutions, this feature can now only be run using an admin account. ■


Printers
Do you trust this printer?
Windows needs to download and install a software driver from the \\Prserver computer to print to Private Printer. Proceed only if you trust the \\Prserver computer and the network.
Install driver
Cancel



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